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THESIS

M21847

COMPOSITE MATERIAL REPAIR AND RELIABILITY

by

Shmuel Maman

March 1989

Thesis Advisor: Edward M. Wu

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Composite structure repair methodology has been developed to specific applications (typically in small area and limited to secondary structure) and is being extended to Large Area Composite Structure Repair (with target extension to primary structures). Therefore, the repair becomes more critical because we get redistribution of stresses that can also affect the zones outside of the repair area. For this reason, an analytic evaluation of the repair's reliability has to be performed to define a parameter which reflects on the effectiveness of the repair.

In this work, we establish a principal guideline to evaluate the redundancy and compare the reliability of the repair to the reliability of the parent structure (i.e., the structure in the undamaged state). The approach adopted is to utilize structural finite element analysis to compute the state of stress at all the spatial elements of structure of the damaged state and of the candidate repaired state. The reliability of these two spatially non-uniform stresses is computed by a probabilistic failure criterion. Thus, we can optimize the repair configuration by varying the strength and the stiffness of any element in the repair site by varying lamination angles, and selectively using hybrid materials.

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Composite Material Repair and Reliability

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Composite structure repair methodology has been developed to specific applications (typically in small area and limited to secondary structure) and is being extended to Large Area Composite Structure Repair (with target extension to primary structures). Therefore, the repair becomes more critical because we get redistribution of stresses that can also affect the zones outside of the repair area. For this reason, an analytic evaluation of the repair's reliability has to be performed to define a parameter which reflects on the effectiveness of the repair.

In this work, we establish a principal guideline to evaluate the redundancy and compare the reliability of the repair to the reliability of the parent structure (i.e., the structure in the undamaged state). The approach adopted is to utilize structural finite element analysis to compute the state of stress at all the spatial elements of structure of the damaged state and of the candidate repaired state. The reliability of these two spatially non-uniform stresses is computed by a probabilistic failure criterion. Thus, we can optimize the repair configuration by varying the strength and the stiffness of any element in the repair site by varying lamination angles, and selectively using hybrid materials.

TABLE OF CONTENTS

I. INTRODUCTION 1
  A. BACKGROUND 1
  B. STRUCTURAL REPAIR DESIGN 2
II. STRUCTURAL REPAIR APPROACH 4
  A. GENERAL CONCEPT 4
  B. FUNCTIONALITY AND RELIABILITY 4
  C. CONSIDERATION 11
  D. TRADE OFF 14
III. STRUCTURAL RELIABILITY (CONCEPT) 15
  A. GENERAL CONCEPT 15
  B. FAILURE MODEL– WEIBULL DISTRIBUTION 17
  C. SIZE– EFFECT 19
IV. REPAIR METHODOLOGY 21
  A. TYPICAL REPAIR REQUIREMENT 21
  B. CONFIGURATIONS FOR REPAIR 22
    1. Parent Structure Configuration 22
    2. Damage Structure Configuration 23
    3. Repair Configuration 23

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C. FINITE ELEMENT APPLICATION 23

V. **METHODOLOGY FORMULATION** 26

A. ONE-DIMENSIONAL EXAMPLE 27

B. TWO-DIMENSIONAL EXAMPLE 30

C. ANALYSIS IN THREE DIMENSIONS 33

D. SUMMARY 34

VI. **CONCLUSIONS** 35

APPENDIX A DESCRIPTION OF ADINA 37

APPENDIX B VERIFICATION PROBLEM 41

APPENDIX C POST-PROCESSOR PROGRAMS 46

APPENDIX D APPLICATIONS 93

LIST OF REFERENCES 151

INITIAL DISTRIBUTION LIST 152

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I. INTRODUCTION

A. BACKGROUND

Composite materials are being utilized for commercial and military applications. Their combination of superior mechanical properties (especially the redundancy), design versatility, and low mass density make them attractive structural materials. Principal applications of composites have been on aircraft, especially on fixed-wing aircraft (e.g., F-18, F-16, F-15, F-14).

As the structural use of composite material on aircraft increases, procedures to repair damage become essential. Composite repair programs have been undertaken both by commercial and military sources [Ref. 1]. Repair concepts have been developed which include bolted patches repairs and bonded patches repairs. At the beginning, the repair technology was targeted for specific applications, typically limited to small areas in secondary structures. More recently, repair techniques have been extended to larger areas, with target extension to primary structures (which inherently have high strength and durability requirements). The particular techniques developed to repair a given component are dependent on the availability of specific facilities and the level of structural integrity.

Under Reference 1, repair procedures were developed for two repair configurations. The configurations that were considered are a scarf inclusion and an external patch. A portable repair kit was developed to provide vacuum pressure and heat in an integral rubber blanket. These techniques permit repairs, verified by testing, that are capable of restoring between 80 percent and 100 percent of the parent laminate ultimate allowable loading.

B. STRUCTURAL REPAIR DESIGN

Repair methodology development through testing has several inherent limitations. Only a specific structural configuration can be examined and optimized for variation of repair configuration in terms of the resultant effectiveness. A large number of experiments are frequently impractical due to economic and time constraints. This calls for the establishment of an analytical principle to guide repair optimization.

In designing repair of composite structures, the external loading is known and the objective is to restore the structural *functionality* while recovering the *overall* structural *reliability*, which includes both the repair and the parent structure. The stiffness of the repair segment and the strength of its attachment may both influence the overall structural reliability by altering the state of stresses in the parent structure. Thus, a repair segment with high stiffness and strong attachment may cause structural failure elsewhere, resulting in a strong repair but a weaker overall structure. On the other hand, a repair with proper stiffness but with insufficient attachment strength may fail in the attachment, also resulting in a low structural reliability.

For these reasons, an appropriate repair methodology for restoring the functionality and recovering the maximum reliability has to be identified. The joint reliability of the structure—the repair segment, the attachment, and the parent structure—must be simultaneously considered by computing the reliability of each part associated with its respective stress states. The joint reliability of the structure can be used as a parameter which characterizes the overall effectiveness of the repair. Based on this parameter, any general configuration of structure and repair can now be evaluated and optimized.

This investigation identifies and outlines the principal steps associated with such an analytical optimization of general structural repair.

II. STRUCTURAL REPAIR APPROACH

A. GENERAL CONCEPT

A vital attribute of composite materials is structural redundancy. In order to identify the appropriate repair methodology for composite structures, the underlying redundancy must be considered.

The objective of repair is to restore the redundancy, even at the expense of increasing the stresses. In other words, our goal is to restore the functionality and to maximize the recoverable reliability of the whole structure. The effect of the repair on the entire structure needs to be considered (i.e., the redistribution of the stresses caused by the damage, and later the repair itself which may transfer the failure to a different location).

B. FUNCTIONALITY AND RELIABILITY

To restore the functionality, elements such as the type of aircraft component and aerodynamic (smoothness) need to be examined.

From the strength theory for composite materials, the main factors that are peculiar to laminate strength analysis (neglecting the thermal effects) are:

- laminae strength
- laminae stiffness
- laminae orientation
- laminae thickness
- stacking sequence

Thus, for restoring the reliability (redundancy), we need to optimize the patch stiffness through the materials selection and the lay-up orientation (including stacking sequence), together with different lap-joint configurations (scarf, step, or external patch). Moreover, the optimization objective is to achieve equal reliability in the parent structure, the joint (the adhesive), and the repair patch, thereby achieving the highest possible total reliability for the entire structure. Upon the development of analytical computation methods for the joint reliability of the entire structure, the optimal repair configuration may be analytically sought by "iterating the choice of material (including hybrids), the orientations of the repair patch, and the joint configurations." Figure 2.1 is an example.

A composite material structure with a repaired area is subjected to a complex loading, as shown in Figure 2.1. To evaluate the reliability, the stresses in each spatial location need to be determined through the stiffness and material iterations.

This example is a boundary value problem, and for that the linear elastic field equations must be satisfied (see Ref. 2).

Due to the external load (T_i-surface traction vector), the stress boundary equation is considered,

$$T_i = \sigma_{ij} \nu_j \qquad i, j = x, y, z \qquad (2.1)$$

where (σ_{ij}) is the normal and shear stress components and (ν_j) is the unit outer normal vector to the surface.

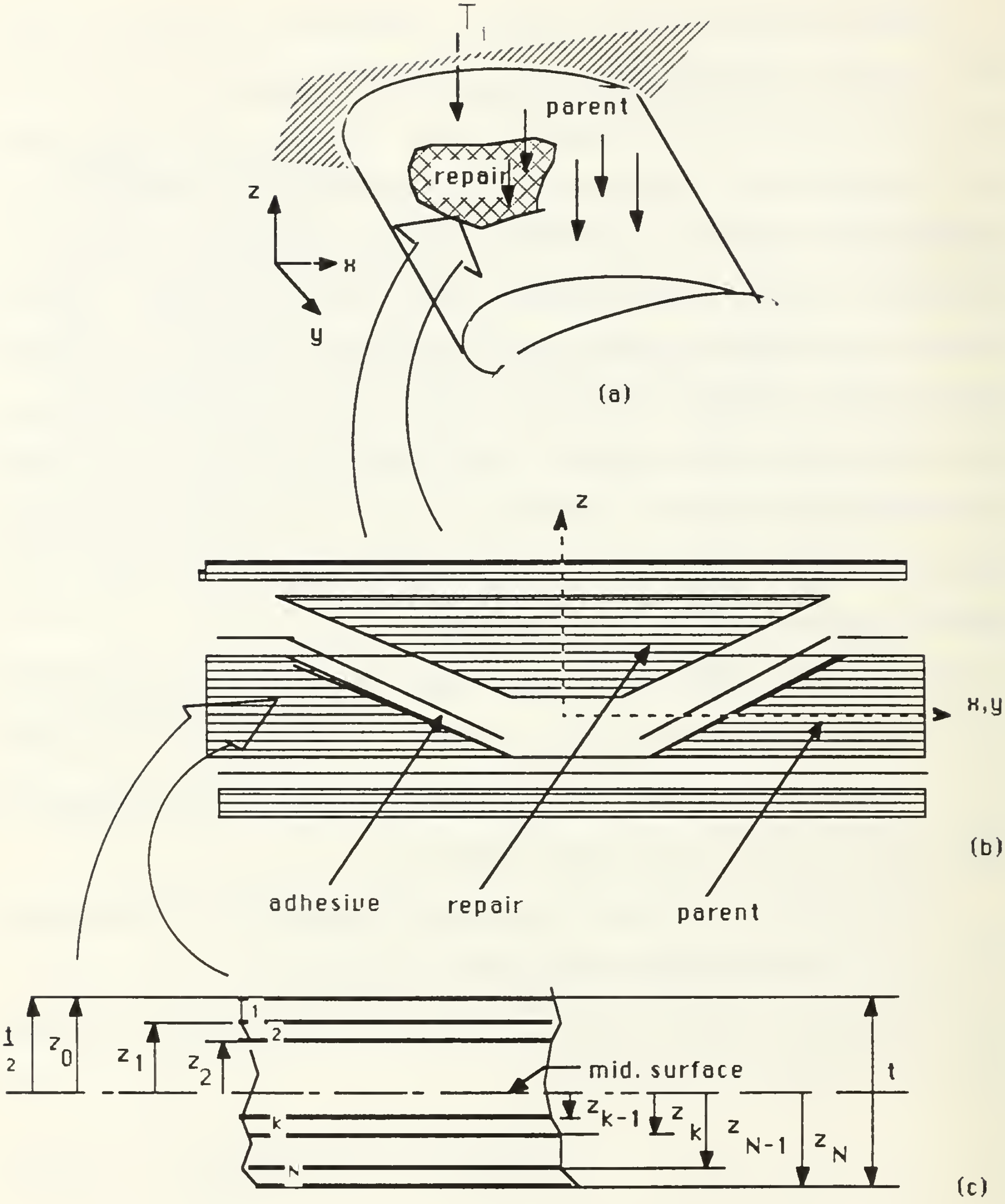


Figure 2.1. **Typical Repaired Structure**

Due to the kinematics, the strain-displacement relations are defined (for small displacements):

$$\varepsilon_{ij} = \tfrac{1}{2}(\partial_i u_j + \partial_j u_i) \qquad i, j = x, y, z \qquad (2.2)$$

where (ε_{ij}) is the strain components and u_i is the displacement.

Substituting the strains into the constitutive relation,

$$\sigma_{ij} = c_{ijlm}\varepsilon_{lm} \qquad i, j, l, m = x, y, z \qquad (2.3)$$

where c_{ijlm} is the stiffness matrix.

Hence, the resulting stresses are determined by satisfying the equilibrium equation,

$$\partial_i \sigma_{ij} + X_j = 0 \qquad i, j = x, y, z \qquad (2.4)$$

where X_j is the body force (usually ignored in the analysis).

Now, recall from the constitutive relation (equation 2.3) that the stiffness matrix (C_{ijlm}) characterizes the material property. In contrast to isotropic material, where the stiffness consists of two independent constants, and more importantly, the stresses are continuous, in an orthotropic composite material the stiffness matrix consists of nine independent constants, which reduce to five for special orthotropic orientation (because with respect to material properties Z and Y axes are equivalent). In a laminate, when the material principal axes are off the structural axes and there is symmetry about z = 0, the stiffness matrix consists of 13 independent constants. Moreover, the stresses are continuous across the thickness (t), and the stiffness is a function of the lamina orientation and the stacking sequence.

For a thin lamina under plane stress, the constitutive relation can be expressed as [Ref. 2]:

The stress-strain relation is

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & Q_{16} \\ Q_{12} & Q_{22} & Q_{26} \\ Q_{16} & Q_{26} & Q_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_{xy} \end{Bmatrix} \tag{2.5}$$

where the Q_{ij}, the so-called reduced stiffnesses, are the C_{ijlm} stiffnesses specialized for plane stress condition in an orthotropic material, and written in contracted notation (i, j = 1, 2, 6).

The stress-strain relation can be related to the kth lamina, and later (for FEM) to the nth element,

$$\{\sigma_{ij}\}_k = [Q_{rs}]_k \{\varepsilon_{ij}\}_k$$

$$i, j = x, y, z \quad r, s = 1, 2, 6 \tag{2.6}$$

From the laminate plate theory [Ref. 2], the resultant external force acting on the laminate shown in Figure 2.2 is obtained by integration of the stress in each lamina through the laminate thickness. For example,

$$N_x = \int_{-\frac{t}{2}}^{\frac{t}{2}} \sigma_x dz$$

$$M_x = \int_{-\frac{t}{2}}^{\frac{t}{2}} \sigma_x z dz \tag{2.7}$$

where N_x is the force per unit length of the cross-section of the laminate. Similarly, M_x is a moment per unit length.

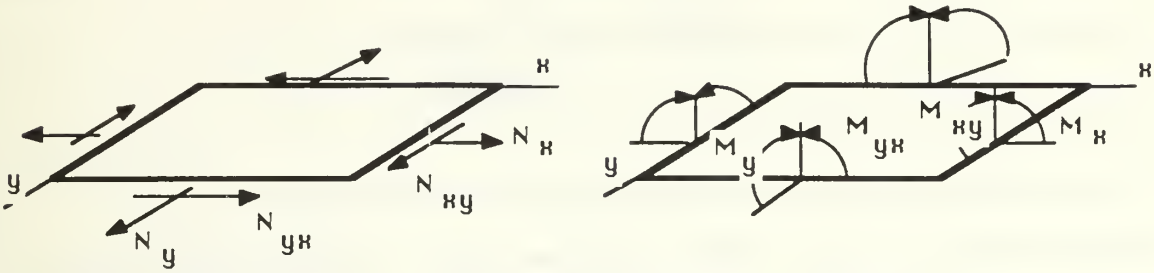


Figure 2.2. **In-Plane Forces and Moments**

Finally, by substituting equations 2.5 and 2.2 into equation 2.7, and summing the forces (N_{ij}) and the moments (M_{ij}) for the whole structure, the following relations are derived [Ref. 2].

$$\begin{aligned}\{N_{ij}\} &= [A_{rs}]\{\varepsilon^0_{ij}\} + [B_{rs}]\{k_{ij}\} \\ \{M_{ij}\} &= [B_{rs}]\{\varepsilon^0_{ij}\} + [D_{rs}]\{k_{ij}\}\end{aligned} \tag{2.8}$$

where

$$A_{rs} = \sum_{k=1}^{N} (Q_{rs})_k (z_k - z_{k-1})$$

$$B_{rs} = \tfrac{1}{2} \sum_{k=1}^{N} (Q_{rs})_k (z_k^2 - z_{k-1}^2)$$

$$D_{rs} = \tfrac{1}{3} \sum_{k=1}^{N} (Q_{rs})_k (z_k^3 - z_{k-1}^3)$$

$$\begin{Bmatrix} k_x \\ k_y \\ k_{xy} \end{Bmatrix} = - \begin{Bmatrix} \dfrac{\partial^2 w_0}{\partial x^2} \\ \dfrac{\partial^2 w_0}{\partial y^2} \\ 2\dfrac{\partial^2 w_0}{\partial x \partial y} \end{Bmatrix} \tag{2.9}$$

ε^0_{ij} and k_{ij} are middle surface values (not functions of z), ε^0_{ij} is the strain component, k_{ij} is the curvature, and w_0 is the displacement of the middle surface in the z direction. t is the thickness and z_k is defined in Figure 2.1(c). In equations 2.8 and 2.9, A_{rs} is called the extensional stiffness, B_{rs} is called coupling stiffness ($B_{rs} = 0$ if the laminate is symmetrical), and D_{rs} is called the bending stiffness.

Therefore, the stiffness in composite material is not dependent only on the material stiffness (Q_{rs}) but also on the laminae thickness ($t = z_k - z_k - 1$) and the stacking sequence (z_k). The stiffness matrix (Q_{rs}) changes due to the orientation of the laminae as it corresponds to the structure coordinates.

In short, to iterate the material stiffness for determining stresses, numerous independent parameters are involved. The parent structure configuration is given (the stiffnesses are known). But in addition, in composite repair, two configurations are concurrently being considered—the parent structure and the repair (shown in Figure 2.1). For each of those configurations, the stresses must be evaluated and by the constitutive relation (equation 2.3) they must match in their boundaries. Before repairing the damage, the parent structure with a "hole" configuration needs to be iterated, and then the repaired structure configuration. Through the resulting spatial non-homogeneous stresses, it is impractical to *a priori* determine which configuration is optimal (i.e., as can be done for isotropic material). Thus, by calculating the total reliability from the state of stresses, we unify all the identified parameters into one single parameter for optimizing the repair configuration.

C. CONSIDERATION

In this investigation, we assume that the functionality of a repaired structure must be the same as before damage, so the repair effectiveness is measured by the post-repair reliability. To evaluate the reliability, comparisons of the structure before damage, before repair, and after the repair need to be done (see Figure 2.3).

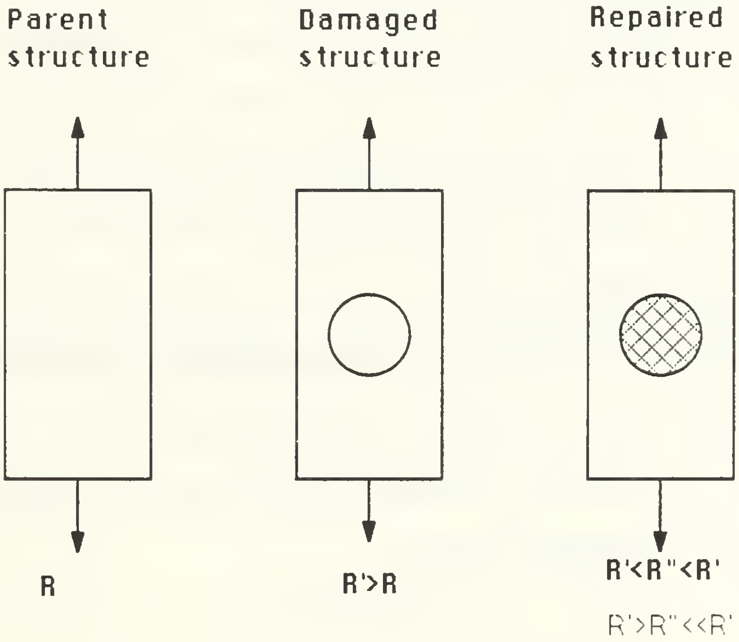


Figure 2.3. **Repair Configurations**

The merits of the different elements of design of the repair can be consolidated into one single unified parameter and measured by the structural reliability.

From the general concept of reliability, the number of probable failures is associated with the magnitude of the stress level (the random variable). For a structure of given dimensions, *the higher the stress level the higher the probability of failure.* The quantitative probability of failure can be computed if the cumulative distribution of failure is known. For a structure under non-uniform stress (spatial heterogeneous stress), the structure may be visualized as being divided into contiguous geometric elements within which the stresses are uniform. The reliability of each element corresponds to the respective stress magnitude of that element. Equivalently, the magnitude of the stress at each spatial location of the structure can be thought of as being mapped into a respective point on the stress space (by appropriate stress analysis). If all the stress magnitudes are within the domain bounded by the strengths, then the entire structure is considered to be safe, as shown in Figure 2.4.

The mapping of the physical spatial location to the stress domain is carried out in stress analysis. The definition of the strength in the stress domain is a failure criterion which can be defined either deterministically or probabilistically.

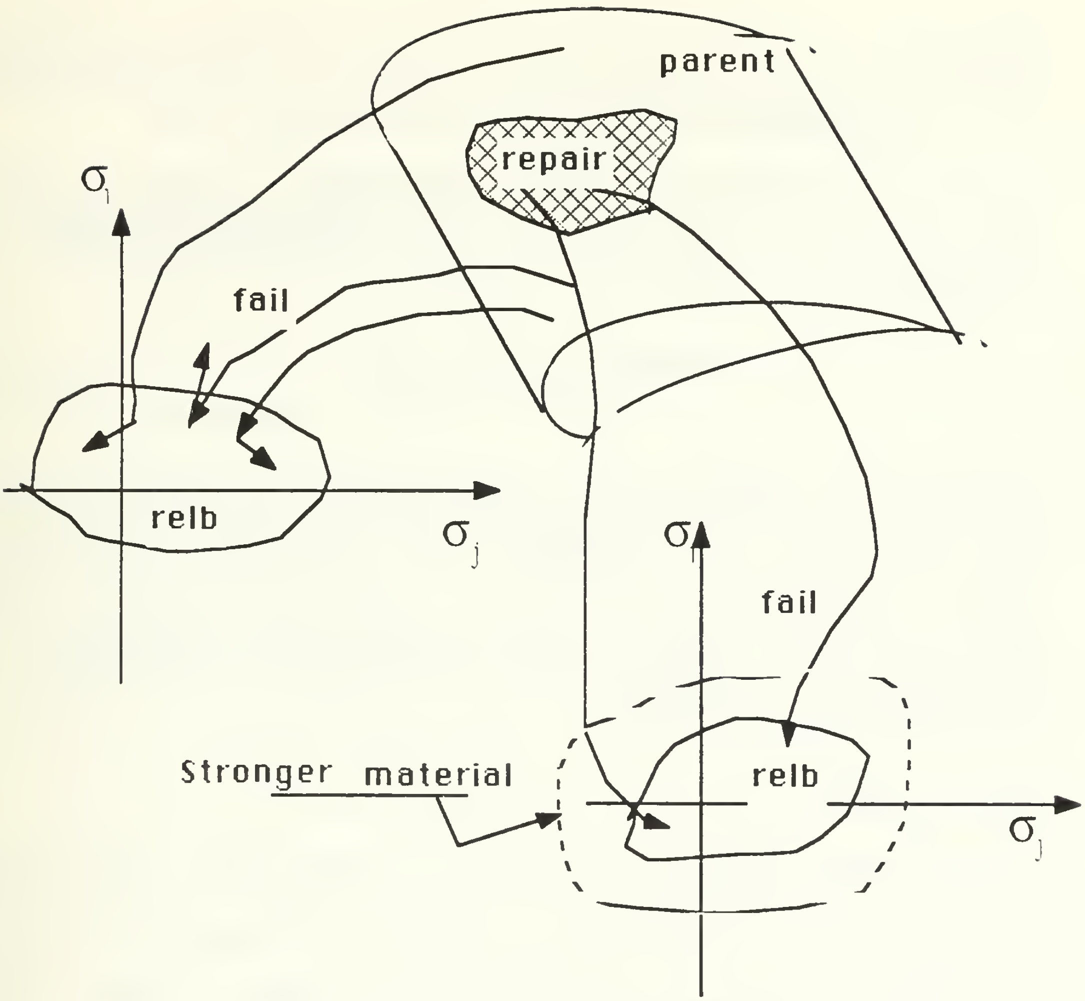


Figure 2.4. **Reliability Criterion**

1. A deterministic failure criterion can expressed in terms of the scalar stress components, which are themselves a function of the spatial location of the structure.

$$f(\sigma_{ij}(x_k)) < 1 \qquad \text{safe}$$

$$f(\sigma_{ij}(x_k)) > 1 \qquad \text{fail} \tag{2.10}$$

where σ_{ij} is the stress component in tensor notation (i = 1, 2, 3) and x_k is the spatial coordinates within the structure. F(.) is a function representing the contour separating all the safe stress states from all the non-safe states. For example, for coupled strength. F(.) may be expressed in terms of a polynomial criterion, as described in Reference 3.

2. A probabilistic failure criterion expressed in terms of scalar stress components as random variables. The magnitudes of the scalar stress are themselves a function of the spatial location of the structure.

$$R = R\left((\sigma_{ij})_k, x_k, \alpha_k, \beta_k\right) \tag{2.11}$$

where R is the reliability of a physical element located at spatial coordinates x_k within the structure, under stress components $(\sigma_{ij})_k$. α_k and β_k are the statistical parameters of the probabilistic failure model associated with the component stress σ_{ij}. The entire structure is safe if the joint reliability for assemblage of all the spatial locations of the structure is greater than or equal to the reliability specification.

D. TRADE OFF

In the spirit of the consideration above, the joint reliability is consorted measure of the all the parameters which need to be optimized for a given repair. To explore the effects of the repair, which include the size of the damage area (after the clean-up) and the patch type (material, stiffness, and type of joint), trade-offs between stiffness and strength of the specific parent structure, the joining segment, and the repair patch need to be considered.

If, when the repair design is completed, the structural reliability is not met, the design parameters need to be iterated to an achieve an acceptable solution. This iteration involves the redesign of the structure/ repair configuration and the selection of new material and/or a new lay-up configuration.

III. STRUCTURAL RELIABILITY (CONCEPT)

A. GENERAL CONCEPT

In Chapter II, we developed the repair design concept as it relates to reliability. In this chapter, we will explore the specifics of stresses and strength calculations and examine their relationship to reliability. This relation allows us to compute reliability based upon the failure criterion which is most appropriate to the specific composite under consideration.

Historically, formulation of many failure criteria was intuitively taken to be mechanistically based on failure mechanisms, but in fact the criteria are phenomenological (because frequently, the plane of failure does not necessarily correspond to applied stress). Phenomenological failure criteria represent (describe) failure states but do not explain failure causes (or mechanism). There is no uniquely "correct" formulation, and there is no *a priori* known formula.

The failure modes observed for composite materials are quite unlike those observed for isotropic homogeneous materials because of their anisotropic and heterogeneous nature. Nevertheless, it is essential for design to predict the capability of the structural element under a complex loading. Judgment must be made as to whether the theory (analytical results) adequately represents (for a wide class of problems) the physical phenomenon (i.e., experimental results).

In the design of repair, we are looking at the parent structure characteristic and the repair characteristic as a whole system's ability to withstand a given load. Then, by the reliability characterization we determine the stress level (coming from the applied load), for which there is an acceptable number of probable failures.

In a composite material, the lamina is the basic building block which consists of fibers imbedded in a matrix. In composite structure, especially in repair areas, the stresses are spatially heterogeneous, both in forms of stress components and in their magnitudes. Moreover, because the lamina is composed of numerous fibers and possesses inherent redundancy, the composite failure process is sequential (in stress level). At the same time, the actual behavior of the loaded structure often exhibits considerable data scatter in measured strength due to processing variability (which is unavoidable in large composite structures).

(Anisotropic) failure criteria are mathematical functions (analytical, numerical, graphical) which define the stress levels below which a structure is safe. If the measure of safety is absolute, the failure criteria are deterministic; otherwise, the failure criteria are probabilistic. The magnitude of stress (one component for 1-D; six components for 3-D) at each spatial location of the structure is mapped into a respective point in the stress space. If all the points are within the domain bounded by the strengths, then the entire structure is safe. Ideally, a failure criterion should capture the physics of the specific failure process and the sequential events of failure.

Therefore, in order to calculate the reliability of a structure with non-uniform stress, the state of stress at every spatial location needs to be computed. The influence of these stresses on the respective reliability in those specific spatial locations can then be evaluated by an appropriate probability model.

B. FAILURE MODEL—WEIBULL DISTRIBUTION

In 1958(?), Rosen recognized that the mechanism of composite failure originated from the statistical variability of the fiber strength [Ref. 6]. The failure process was observed to be sequential, initiating from failure of weak fiber sites; the load originally carried by the weak fibers is transfered to the adjacent strong fibers, thereby postponing immediate failure. Upon additional load increase, the local micro-redundancy is insufficient to sustain the stress concentration, leading to catastrophic macroscopic failure of the composite. Harlow and Phoenix [Ref. 4] refined the probabilistic modeling of sequential failure events and arrived at the "chain-of-bundle" model. The composite structure is modeled as a chain of bundles in series. Each bundle has length δ, generally referred to as the "ineffective length." The ineffective length is a function of the matrix stiffness and the interfacial bound strength; it is analytically estimated to be an order of magnitude greater than the fiber diameter (the diameter of graphite fiber is around 5 μm). Each bundle is assumed to be independent and identically distributed, and the cumulative distribution function (CDF) can be expressed in terms of the fiber statistics. Harlow and Phoenix have also derived, by analytical recursive formulation, the statistical strength behavior of large composite from small bundles. Since the bundles are in series, the weakest link function is applied. For filament strength, the Weibull model is appropriate for the characterization of the strength statistics. For the composite, the strength may be considered as piece-wise Weibull, where the scale and shape parameters are modified by the Harlow-Phoenix chain of bundle calculations.

For this investigation, we consider each spatial element as independent and ignore failure sequence and subsequent load distribution. This is equivalent to stating that *if one point in any direction fails, the whole structure fails* (failure can occur in any element of the structure, in either the parent structure or in the repaired portion of the structure). The reliability under this condition can be calculated given the failure distribution and the failure criterion.

We use the Weibull distribution with parameters adjusted by the "chain-of bundle" model. The two-parameter Weibull distribution is expressed as:

> For any i^{th} spatial location (considered in our calculation as an element), the failure distribution function (CDF) is:

$$F\left(\sigma_i(x_j);\beta_i,\alpha_i\right) = 1 - \exp\left\{-\left(\frac{\sigma_i}{\beta_i}\right)^{\alpha_i}\right\} \qquad (3.1)$$

where

s_i— stress component at location x_j

β_i— the location parameter, representing the strength under the respective stress component (σ_i). It is dependent on the size of the element.

α_j — the shape parameter, representing dispersion of the failure function. It is also dependent on the size of the element.

Then, the reliability at each point, $\sigma_i(x_j)$

$$R(\sigma_i) = 1 - F\left(\sigma_i;(x_j)\beta_i,\alpha_i\right) \tag{3.2}$$

$$R(\sigma_i) = \exp\left\{-\left(\frac{\sigma_i(x_j)}{\beta_i}\right)^{\alpha_i}\right\} \tag{3.3}$$

Assuming that the failure (β_i) event is independent of all spatial locations, the total structure reliability (R_T) can be represented by:

$$R_T = R_1 R_2 \cdots R_K$$

$$R_T = \prod_1^K R_K \tag{3.4}$$

where (R_K) is the reliability at each spatial location.

C. SIZE—EFFECT

In our approach, for calculating the state of stress we are using a finite element method (FEM). For that we assume that a configuration of repaired structure is partitioned into geometric meshes n of size 1 and m of size 2. The intrinsic strength of each element may be different. The choice of element size is arbitrary, and because the same structure is under consideration, the total reliability must remain the same.

$$R_T = R_1^n = R_2^m \tag{3.5}$$

where

R_T — the total reliability

R_1, R_2 — The element reliability (assume equal for simplicity) of each meshing.

n — number of element for size 1

m — number of element for size 2

By Weibull distribution,

$$\exp\left\{-\left(\frac{\sigma}{\beta_1}\right)^{\alpha} n\right\} = \exp\left\{-\left(\frac{\sigma}{\beta_2}\right)^{\alpha} m\right\} \tag{3.6}$$

We make the simplifying assumption that the two different sizes are not drastically different so that the same shape parameters α can be used. It follows that:

$$\frac{\beta_2}{\beta_1} = \left(\frac{m}{n}\right)^{\frac{1}{\alpha}} \tag{3.7}$$

Therefore, we can evaluate the reliability of each element by relating its length or area to the unit element. In our approach, the reliability is normalized by the smallest element. The smallest element is assumed to be the ineffective size. In short, we need to first perform stress analysis, which is in sections, then evaluate the reliability knowing the strength of the smallest element.

IV. REPAIR METHODOLOGY

A. TYPICAL REPAIR REQUIREMENT

The previous chapters discussed the rationale of adopting the joint reliability as a single indicator of the repair efficiency and the property of a probabilistic failure criterion which is required to calculate the reliability of each spatial element under a non-uniform complex state of stress. Furthermore, we identify the following requirements which are necessary to establish the appropriate repair methodology for composite structures with the goal of restoring the structural integrity:

1. The entire structure needs to be considered.

2. The patch stiffness through the materials selection and the lay-up orientation, together with different lap joint configuration, need to be optimized. The optimizing objective parameter is the joint reliability of the structure, including the parent structure, the joint, and the repair patch. The objective is not to maximize the reliability of the repair but rather to achieve highest possible total reliability for the entire structure.

3. In order to assess the necessity or the effectiveness of the repair, a single parameter is formulated. We select reliability as the parameter (refer to Chapter III).

4. Using the reliability formulation, the parent structure reliability is compared to the damaged structure reliability before repair, and the repaired structure reliability. As mentioned previously, the ideal repair restores the reliability of the repaired structure.

5. It is known that conventional repair depends on the adhesive joint, which always has no redundancy or poor redundancy (smooth-joint versus step-joint). This weakness has to be taken into account. In our approach, the adhesive strength affects the stress distribution and limits the repair stiffness (see joint configuration in appendix). Thus, the joint strength is considered

with the stiffness optimization (lay-up design) of the repair segment (i.e., weak adhesive limiting the transferring of stresses to the repair segment compliant patch)

6. To simplify the calculation, and to reduce the number of parameters that have to be iterated in the same time, we assume the adhesive reliability to be equal to 1. In other words, we assume infinite joint reliability.
7. The reliability of the structure is the product of the reliability of the individual elements (see equation 3.4). Moreover, to achieve the reliability of the element, it is required that the magnitude of the stress tensor not exceed the failure criterion (i.e., a spatial reliability function with stress tensor as the random variable (see Chapter II).

B. CONFIGURATIONS FOR REPAIR

Now, in order to utilize the appropriate procedure for designing a repair, we have to consider three separate configurations:

1. The parent structure
2. The damaged structure
3. The repair

1. Parent Structure Configuration

For the parent structure, a finite element model must be built to represent the original geometry, the lamination configuration, and the original material. The boundary conditions are determined by the actual external load and reactions (support).

By knowing these data, the resulting stress tensor for each element can be calculated. Using the suitable failure criteria, the parent structure reliability (R0) can be evaluated. The parent structure reliability is the acceptable parameter reference to compare for optimizing the repair configuration.

2. Damage Structure Configuration

We assume that all the facilities needed to evaluate the damage area are available (i.e., NDT). Thus, before removing the damage and preparing the area for the bonding repair, the clean-up geometry has to be optimized. Dependent on the size of damage, the spatial location, the repair capability, and the state of load in this area (considering the fibers' orientation), several configurations can be evaluated. Again, going through the same procedure introduced for the parent structure, the state of stress is calculated and thereby the reliability for each configuration, R1, R2, R3. Now the configuration with the largest reliability (say R3) is selected.

3. Repair Configuration

Starting with the R3 configuration, and assuming infinite joint reliability, the joint strength is considered with the optimized stiffness. Thus, only the reliability of the parent structure (outside of the repair zone) and the reliability of the repair structure (the patched zone) are considered for calculating the total repaired structure reliability. To optimize the repair configuration in the lay-up design, one must control the repair stiffness and redistribution of the stresses. Either one type of material can be chosen and only the lamination can vary (lamina orientation) or more than one material and lamination can be applied.

C. FINITE ELEMENT APPLICATION

It has been shown that to calculate the reliability, we need to analyze the state of stress in all spatial locations— analytical boundary value problems or finite element methods (FEM) can be used. Because of the complexity of the structure geometry, it is essential to use FEM (refer to ADINA code in Appendix A).

The analysis of stress in a laminate of laminae is straightforward. For 2-D problems, we are using the laminate plate theory (plane stress). For 3-D problems, we are using generalized calculations for orthotropic materials. Assuming the laminae exhibits linear elastic behavior, the stresses seen to be a linear function of the applied loads. That is, if all laminate stresses in each laminae (i.e., corresponding to an element in ADINA code) are known, then the stresses in each laminae can be compared with the lamina failure criterion (see Chapter III) and uniformly scaled to determine the load at which failure occurs and the spatial location.

In accordance with the reliability and failure criteria, all failure criteria for laminates depend on the strength in the principal material direction, which likely does not coincide with principal stress directions. Therefore, the strength in each lamina in a laminate must be assessed in a coordinate system that is likely different from those of its neighboring laminae. (This coordinate mismatch is one of the complications that characterizes the determination of the failure criteria.)

Hence, for the interpretation of stresses resulting from the FEM calculation, all the stress tensors have to be transformed to the principal material direction per lamina (see Appendix C).

Furthermore, in order to normalize the reliability and to make it geometrically independent, the area of each element has to be related to an acceptable minimum area. The minimum area is derived from the minimum size effect.

V. METHODOLOGY FORMULATION

The object of this chapter is to explore the effects of the damage, and finally the repair, on the stresses of the entire structure. Appropriate simplifying assumptions have been represented in the the repair methodology (Chapter II).

We wish to capture the essence of the underlying mechanics and physics of our problem. The field equations in solid mechanics are specialized for calculating the state of stress in the repaired structure. Then, the acceptable probabilistic failure criteria, expressed as a mathematical function which defines the stress level below which the structure is safe, is utilized.

Therefore, in the context of preliminary sizing and design trade-offs of the repair, and also for confirmation of output of more accurate analysis carried out by the computer code, we represent the repair methodology by the following formulations.

The formulations are classified by :

1. The physical space—a line, a plane, a volume
2. The stress space—one component, three components, six components
3. The spatial distribution of stress within the structure—homogeneous or heterogeneous
4. The definition of safety—for our case, probabilistic failure criteria

Whereas in one-dimensional theory (1-D uniaxial stress), each scalar stress is mapped into a respective point on a line (1-D) in the stress space, under planar combined stress, the magnitude of stress (three components) at each spatial location of the structure is mapped into a respective point on the 3-D stress space. Under general combined stress, the magnitude of stresses (six components) at each spatial location of the structure is mapped into a respective point on the 6-D stress hyperspace.

Stress interior to domain bounded by the failure surface → safe.

Stress exterior to domain bounded by the failure surface → not safe.

A. ONE-DIMENSIONAL EXAMPLE

In order to understand the methodology principle, a simple stress analysis, consisting of a scalar calculation for single component stress, is shown in the following example.

A long segment (shown in Figure 5.1) of non-uniform cross-sectional area (A(x)) is subjected to a uniaxial tension load (P). Then, to calculate the reliability:

1. The long segment is divided to small and unequal elements, because of the usual complexity of the repair geometry (geometry mapping) and because of different stress magnitude distributors (i.e., the segment is spatial stress heterogeneous).

2. The stresses ($\sigma(x)$) are uniaxial stress (1-D) and must be evaluated in each spatial location. Thus, because of uniaxial stress (one component, 1-D), the stress analysis is simple and represented by

$$\sigma(x) = \frac{P}{A(x)} \qquad (5.1)$$

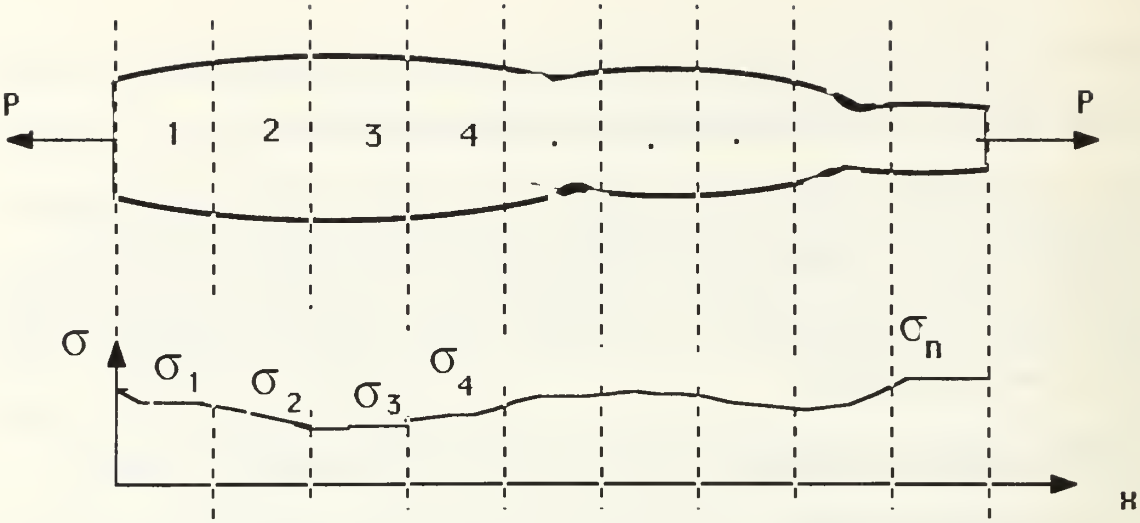


Figure 5.1. **Long Segment, Non-Uniform Stresses**

Therefore, because of the series process assumed for composite material structure (refer to Chapter II), the total reliability of the structure (R_T) is presented as a function of the stress and the element size,

$$R_T = \prod_{i}^{n} R((\sigma_i(x)), \Delta x_i) \quad i=1, 2 \ldots n \tag{5.2}$$

where

n— the number of elements

Δx_j— is the i^{th} element length

Furthermore, using the Weibull distribution function (weakest link of chain), the total reliability is expressed as,

$$R_T = \prod_{i}^{n} \exp\left[-\left(\frac{\sigma_i}{\beta_i}\right)^{\alpha_i}\right] \tag{5.3}$$

3. To compare the structure configuration (i.e., for different load, different type of repair), and to avoid size effects on the strength of the material, the reliability must be geometry independent.

Thus, the reliability is normalized by the smallest length, as follows.

Using the weakest link rule [Ref. 4], and assuming the shape function is constant (in composite material α = 5~10), the size effect is represented by,

$$\frac{\beta_i}{\beta} = \left(\frac{\delta}{\Delta x_i}\right)^{\frac{1}{\alpha}} \tag{5.4}$$

$$\beta_i = \left(\frac{\delta}{\Delta x_i}\right)^{\frac{1}{\alpha}} \beta \tag{5.5}$$

where

δ – the length of the smallest element

β – the mean strength value of the smallest element (evaluated by experiments)

β_i – the mean strength value of the ith element.

Then, by substituting equation 5.5 into equation 5.3, the total reliability is obtained as:

$$R_T = \prod_i^n \exp\left[-\left(\frac{\sigma_i}{\beta}\right)^{\alpha} \frac{\Delta x_i}{\delta}\right] \tag{5.6}$$

4. Finally, a simulation needs to be performed to demonstrate the probability of different loading configurations. This simulation was carried out via a statistical analysis using the spreadsheet Microsoft Excel on a Macintosh computer (see Reference 9). There, the strength is evaluated by the Weibull distribution function (weakest link), and if any stress is larger than the suitable strength, then the structure fails (1 – fail, 0 – no fail).

   Thus, after several runs of the simulation, we can observe that *the location of highest stress has the highest probability of failure but not a certainty of failure.* In other words, the failure is not constant due to the spatial location – it is changing according to the probabilistic failure criteria. The resulting reliability distribution is compared so the configuration of the structure loading can be optimized.

B. TWO-DIMENSIONAL EXAMPLE

The first approach that corresponds to the macro-mechanical behavior of a composite laminate is the 2- D stress calculation using the classical lamination theory [Ref. 2]. Thereby, under the same principle as 1-D calculations, 2-D calculations are performed, considering three stress components:

$$\{\sigma_1, \sigma_2, \sigma_6\}$$

A typical analysis of a thin plate with an elliptical hole subjected to tensile load in a non-principal direction is described. This analysis models the damaged area of a structure after "clean-up" and before the bonding process of the "patch" repair.

Again, going through the same procedure as the 1-D example in order to calculate the total reliability,

1. The physical space considered is the space area of the entire plate (laminate). The space is divided into unequal areas. The rectangular rather than the polar division is preferable because of the orthogonality of the composite material, and because it is easier to compare the structure reliability as a spreadsheet.

2. Assuming an unequal area for each element, the stress analysis is performed.

   Note that for using reliability equations, the stresses in each spatial location must transform to the principal material direction, as explained in Chapter II. For this, stress transformation equations are used [Ref. 2].

   Now, having the stresses in each spatial location, the same procedure as in the 1-D example is utilized. We must remember that, here, the weakest link rule refers to each component of stress in each element (three components). Therefore, the weakest link rule refers to each element in the entire structure (plate).

3. To normalize the reliability, the lengths in the previous example (equation 5.5), are replaced by areas:

$$\beta_{k,i} = \left(\frac{A_m}{A_{k,i}}\right)^{\frac{1}{\alpha}} \beta \tag{5.7}$$

k— relates to the element notation.

i— relates to the stress component (i=1,2,6).

A_m— the smallest element area.

$A_{k,i}$— the kth element area.

4. Therefore, because of the weakest link approach, there are two options to calculate the total reliability (R_T).

Option 1: Calculate the reliability of the whole structure with respect to each component in each element (shear or normal stress), then calculate the total reliability, as shown below.

The reliability of the kth element due to the ith stress component is

$$R_{k,i} = \exp\left[-\left(\frac{\sigma_{k,i}}{\beta_{k,i}}\right)^{\alpha}\right] \quad i = 1,\ 2,\ 6 \tag{5.8}$$

Note that the stresses are in contract notation.

The whole n element's reliability with respect to the ith stress component is:

$$R_{T,i} = \prod_{k=1}^{n} R_{k,i} \qquad k = 1 \ldots n \tag{5.9}$$

Finally, the total reliability is:

$$R_T = \prod_{i=1}^{6} R_{T,i} \qquad i = 1, 2, 6 \qquad (5.10)$$

$$R_T = \prod_{i=1}^{6}\prod_{k=1}^{n} R_{k,i} = \prod_{i=1}^{6}\prod_{k=1}^{n} \exp\left[-\left(\frac{\sigma_{k,i}}{\beta_{k,i}}\right)^{\alpha}\right] \qquad \begin{matrix} i = 1, 2, 6 \\ k = 1, 2 \ldots n \end{matrix} \qquad (5.11)$$

Option 2: calculate the reliability of each element and then calculate the total reliability as follows.

The reliability per element ($R_{E,k}$) is the product of the stress component reliabilities ($R_{k,i}$—expressed in equation 5.8).

Thus,

$$R_{E,k} = \prod_{i=1}^{6} R_{k,i} \qquad i = 1, 2, 6 \qquad (5.12)$$

Then, the total reliability is,

$$R_T = \prod_{k=1}^{n} R_{E,k} \qquad (5.13)$$

And, after substituting equations 5.10 and 5.14 into equation 5.15, the total reliability is:

$$R_T = \prod_{k=1}^{n}\prod_{i=1}^{6} \exp\left[-\left(\frac{\sigma_{k,i}}{\beta_{k,i}}\right)^{\alpha}\right] \qquad \begin{matrix} i = 1, 2, \ldots, 6 \\ k = 1, 2, \ldots, n \end{matrix} \qquad (5.14)$$

Although the total reliability must be the same for any option, a difference exists between the two options and is obtained by the interpretation of optimizing the repair. Through Option 1, we can visualize the effect of a specific stress in a specific direction (i.e., improve fiber, if the total reliability—[$R_{T,i}$—fiber direction], is small). Or, through Option 2, the weakest element which has the lowest reliability ($R_{E,k}$) can be investigated.

C. ANALYSIS IN THREE DIMENSIONS

The next obvious approach is to extend the analysis to a laminate in 3-D physical space considering combined and spatial heterogeneous stresses (six components). Obviously, the stress analysis is more complex and cannot be solved "by hand,"—a numerical analysis method must be used (see application of ADINA code in Appendix A). Moreover, following the same procedure that is used in the 1-D example and in the 2-D example, the total reliability is calculated.

1. The state of stresses resulting from the 3-D analysis (generalized orthotropic laminate—Reference 2), must relate to the mean strength known for laminae (from experiments). In other words, the stress must be calculated per element in the lamina. Therefore, unit volume will have an identical thickness for each element. Hence, the area normalization in 2-D (see equation 5.7) is sufficient also for the 3-D calculation.

2. Furthermore, to calculate the reliability, instead of three components in the 2-D example, we consider six stress components:

$$\{\sigma_1, \sigma_2, \sigma_3, \sigma_4, \sigma_5, \sigma_6\}$$

For the first option mentioned in the 2-D example, equation 5.10 extends to:

$$R_{k,i} = \exp\left[-\left(\frac{\sigma_{k,i}}{\beta_{k,i}}\right)^{\alpha}\right] \quad i = 1, 2 \dots 6 \qquad (5.15)$$

The whole n element reliability with respect to the i^{th} stress remains the same (see equation 5.9). Hence, the total reliability is:

$$R_T = \prod_{i=1}^{6}\prod_{k=1}^{n} R_{k,i} = \prod_{i=1}^{6}\prod_{k=1}^{n} \exp\left[-\left(\frac{\sigma_{k,i}}{\beta_{k,i}}\right)^{\alpha}\right] \qquad \begin{array}{l} i = 1, 2, \ldots, 6 \\ k = 1, 2, \ldots, n \end{array} \qquad (5.16)$$

For the second option mentioned in the 2-D example, equation 5.12 extends to a product of six instead of three, as shown below.

$$R_{E,k} = \prod_{i=1}^{6} R_{k,i} \qquad i = 1, 2 \ldots 6 \qquad (5.17)$$

Thus, similarly to the 2-D example, the total reliability is:

$$R_T = \prod_{k=1}^{n}\prod_{i=1}^{6} \exp\left[-\left(\frac{\sigma_{k,i}}{\beta_{k,i}}\right)^{\alpha}\right] \qquad \begin{array}{l} i = 1, 2, \ldots, 6 \\ k = 1, 2, \ldots, n \end{array} \qquad (5.18)$$

D. SUMMARY

1. The 1-D example is only a simple presentation of the methodology concept used for calculating the total reliability.
2. In the 2-D example, the whole structure analysis is simplified using laminate plate theory. This approach is used in practice to do preliminary calculation and sizing, and to check the results of 2-D and especially 3-D numerical analysis carried out by computer codes (see Appendices A and B).
3. For the 3-D example, the state of stress in each spatial location, considering the generalized orthotropic laminate, is numerically calculated using FEM by computer a code (i.e., ADINA).
4. Comparing 2-D to 3-D as the generalized orthotropic laminate analysis, in 2-D analysis the interlaminar stresses are ignored.

VI. CONCLUSIONS

This work has proposed a primary approach for the designing of composite material repair, using reliability as a single parameter to indicate the most effective repair. Finite element analysis was used to calculate the state of stress at any spatial location (non-uniform and combined), which in turn was used to calculate the resultant reliability. This methodology can be used to assist maintenance personnel in the selection of the optimal repair configuration.

The Weibull distribution function with modified shape and scale parameters was used for estimating the reliability, based on the observation that composite material failure is adequately represented by the weakest link chain-of-bundle model. The best selection of failure criteria has to be confirmed by experiment.

Simulations for different patches under a specific loading or for specific patches under different loading need to be included in the future extension of the repair optimization method. Moreover, an adequate number of samplings (experiments) needs to be performed in order to estimate the underlying Weibull parameters and then to approve the appropriate failure criteria.

Only bonded repairs with infinitely strong adhesives have been considered. Further studies may be extended to apply this approach to consider adhesives with finite reliability and bolted repairs, which are considered as 3-D reliability enhanced (small transverse fibers are included under this category), and to scarf joint geometry approval.

APPENDIX A

DESCRIPTION OF ADINA

A. GENERAL DESCRIPTION

ADINA is a finite element code for automatic dynamic incremental nonlinear analysis. The ADINA system is composed of four main programs: ADINA-IN, ADINA, ADINA-PLOT, and ADINAT. Version 2 (Jan. 1989) was used for this thesis. The sequence of execution of these programs is shown in Figure A-1 [Ref. 6:pp. 1-2].

For our investigation, the ADINA code was used to conduct the stress/strain analysis (3-D/2-D) of an advance composite material structure. Thermal effects were ignored, so the ADINAT program (for heat-transfer analysis) was not used.

The ADINA-IN program generates the input data for the ADINA program and has the ability to graphically check the model. All or part of the model can be drawn from any view desired, including element and nodal numbering.

Coordinates can be input in a local or global coordinate system using cartesian, cylindrical, or spherical coordinates.

ADINA is used for displacement and stress/strain execution, produces the printout file for displacement and stress/strain, and also produce the porthole file for ADINA-PLOT.

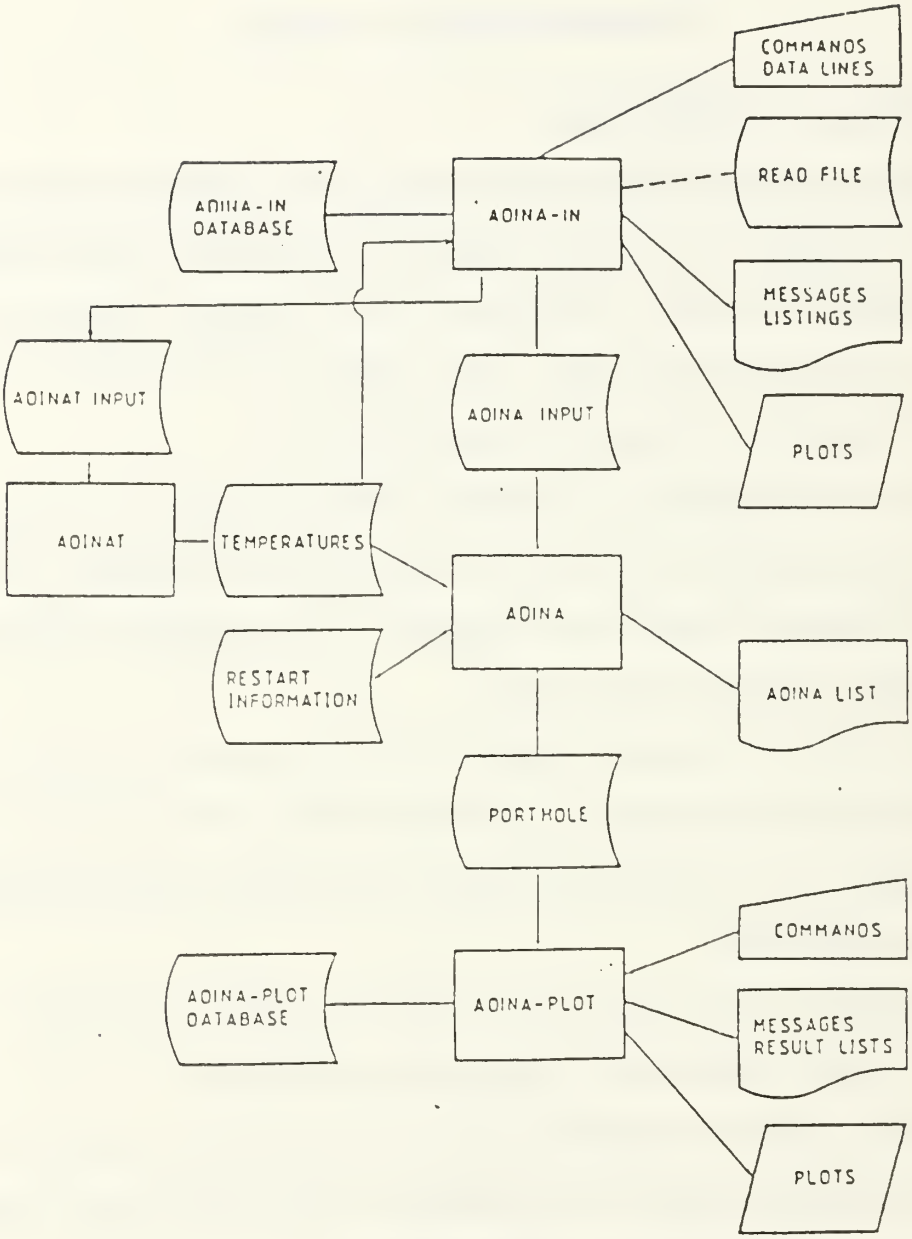


Figure A-1. **Sequence of Execution of ADINA Programs**

ADINA-PLOT performs the post-processing of the output data from ADINA. It also has graphics capability, allowing a view of both the deformed and undeformed shapes, and can do vector plotting of stresses.

B. COMPOSITE MATERIAL IMPLEMENTATION

The program defines the parameters (modulus of elasticity (E_{ij}), Poisson ratio (ν_{ij}) for the orthotropic linear elastic material model [Ref. 6:pp. 5.5–6). The material defined is assigned an identifying number, which can be referenced by several or all of the element groups (i.e., parent structure elements, repair patch elements). The material directions correspond to the global coordinates of the finite element model [Ref. 6:pp. 5.5–7).

In ADINA, the composite material model can be used by several element types: 2-D solid element, 3-D solid element, plate element, and shell element [Ref. 6:p. 5.5–3). In this thesis, the 2-D element and 3-D element type were used.

C. VERIFICATION

Part of the establishment of the repair guideline is the verification of the finite element code. This is done by modeling a problem for which the results are known and comparing numerical with these known results.

The verification includes the geometry verification, material axes definition, and their transformation to the global coordinates, and compares the 2-D (plane stress) solution and the 3-D solution with theoretical solution done by hand.

A simply supported anisotropic square plate, under uniform tensile load along one edge, is considered as a verification problem and discussed in Appendix B.

APPENDIX B

VERIFICATION PROBLEM

A. PHYSICAL PROBLEM

A simply supported anisotropic square plate, under uniform tensile load along one edge, is considered. The plate is built of eight plies and is symmetrical, laminated once with stacking sequence $[90_2/75_2]_s$ and once with stacking sequence $[90_4]_s$.

B. OBJECTIVE

To verify the performance of the 2-D solid plane stress element, and then the performance of the 3-D solid element, when the material is anisotropic.

C. FINITE ELEMENT MODEL

For 2-D analysis, eight-ply thickness plate (laminate) is considered. The mesh consists of three 2-D solid elements (nine nodes). An orthotropic linear elastic material model is used with the principal material axes a and b, making angle beta with the global coordinate axes X and Y, respectively. The laminate stiffness is calculated by the MIC-MAC program [Ref. 7:ch. 7] from the specific sequence and orientation of the laminae in the laminate.

For 3-D analysis, each ply (lamina) is considered separately across the thickness. The mesh consists of 12 3-D solid elements (27 nodes).

The same orthotropic linear elastic material as in the 2-D model is used. The lamina stiffness is used directly in the finite element model.

For any model, through ADINA execution, a printout file is created. The printout file generates a listing of the displacements and the stress/strain for each element. Only the stress/strain results of nodes number 9, for the 2-D problem, or node number 21, for the 3-D problem, are printed. Node 9 and node 21 are located at the element geometric centroid and represent the element mean values for calculating the reliability.

D. SOLUTION RESULTS

The solution results are as expected. For the lay-up of $[90_4]_s$, the stresses in the applied loads direction are the same as the applied loads. No interlaminar stresses are shown (tend to zero). The results of 2-D analysis are in good agreement with the results of 3-D analysis.

For the lay-up of $[90_2, 75_2]_s$ in 3-D analysis, the layers in 90° orientation are carrying more stresses than the layers in 75° orientation, and the interlaminar stresses are shown (they cannot be neglected). In 2-D analysis, because of plane stress assumption, the interlaminar stresses are not shown, and the stresses have the same value as before—they are representing the mean stress.

```
***********************************************
      PROGRAM TRANS2
***********************************************
      INTEGER NLA,NEL
      PARAMETER (NLA=6,PI = 3.1415927 )
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL MO1,MO2,NU12,NU21,EX,EY,EXY
      REAL THETA(NLA),M,N
      REAL Q11,Q12,Q22,Q66,G12,E1(NLA),E2(NLA),E6(NLA)
      CHARACTER*40 ,FNOUT
*
      WRITE (5,*) ' OUTPUT FILE,NAME: '
      READ  (5,'(A)') FNOUT
      WRITE (5,*) 'INPUT MODULUS & POISSON MO1,MO2,NU21,G12 ?'
      READ (5,*) MO1,MO2,NU21,G12
            NU12 = MO2*NU21 / MO1
             Q11 = MO1 / (1-NU12*NU21)
             Q12 = Q11*NU12
             Q22 = MO2 / (1-NU12*NU21)
             Q66 = G12
*
      WRITE (5,*) 'INPUT STRAIN EX,EY,EXY ?'
      READ (5,*) EX,EY,EXY
      OPEN (UNIT=13,FILE=FNOUT,STATUS='NEW')
      WRITE (13,*) 'INPUT : '
      WRITE (5,10) EX,EY,EXY
      WRITE (13,10) EX,EY,EXY
*
      WRITE (5,*) 'INPUT THE ORIENT. OF EA. ELEM. IN DEG. ?'
      WRITE (13,*) 'INPUT: THE ORIENT. OF EA. ELEM. IN DEG. ;
      DO 50 I=1,NLA
         WRITE (5,20) I
         READ (5,*) THETA(I)
         WRITE (13,25) I,THETA(I)
              THETA(I) = THETA(I)*PI / 180.0
50    CONTINUE
*
      WRITE (5,*)'OUTPUT :'
      WRITE (13,*) 'OUTPUT : ',FNOUT
      WRITE (5,60) 'NLA','S1','S2','S3','S6','S5','S4'
      WRITE (13,60) 'NLA','S1','S2','S3','S6','S5','S4'
*
       NEL=0
      DO 90 J=1,3
      DO 80 I=1,NLA
         NEL=NEL+1
*       STRAINS TRANSFORMATION :
            M=COS(THETA(I))
            N=SIN(THETA(I))
            E1(I) = EX*M**2 + EY*N**2 + EXY*M*N
            E2(I) = EX*N**2 + EY*M**2 + EXY*M*N
            E6(I) = -EX*2*M*N + EY*2*M*N + EXY*(M**2 - N**2)
*       STRESSES CALCULATION :
            A(NEL,1) = Q11*E1(I) + Q12*E2(I)
            A(NEL,2) = Q12*E1(I) + Q22*E2(I)
            A(NEL,6) = Q66*E6(I)
            A(NEL,4) = 0.
            A(NEL,5) = 0.
            A(NEL,3) = 0.
```

```
80    CONTINUE
90    CONTINUE
      DO 100 I=1,NEL
        WRITE (13,70) NEL,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
100   CONTINUE
*
      CALL BETA(A,B,NEL)
      WRITE (5,*) 'INPUT ALFA'
      READ  (5,*) ALF
      WRITE (13,40) ALF
      CALL ALFA(A,B,NEL,ALF)
      CALL RELI(A,B,NEL)
      CALL ELRE(B,NEL)
*
10    FORMAT (//,1X,'STRAINX= ',E11.3,8X,'STRAINY= ',E11.3,
     &         9X,'STRAINXY= ',E11.3)
20    FORMAT (1X,'THETA(',I2,')= ')
25    FORMAT (1X,'THETA(',I2,')= ',F6.1)
40    FORMAT (//,1X,'SHAP FUNCTION (ALFA) = ',F5.1/1X,40('-'))
60    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
70    FORMAT (/,4X,I6,6E11.3)
*
      STOP
      END
******************************
      SUBROUTINE BETA(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL X(COLS),X1C,X2C,X3C
*
* PLY STRESS - STRENGTH,RATIO CALCULATION :
*-----------------------------------------
      WRITE (13,10) 'NEL','SR1','SR2','SR3','SR6','SR5','SR4'
      DO 90 I=1,NEL
         X(1)  = 15.0E4
         X(2)  = 0.4E4
         X(3)  = X(2)
         X(6)  = 0.68E4
         X(4)  = X(6)
         X(5)  = X(6)
         X1C = -15.0E4
         X2C = -2.46E4
         X3C = X2C
         IF (A(I,1).LT.0) X(1) = X1C
         IF (A(I,2).LT.0) X(2) = X2C
         IF (A(I,3).LT.0) X(3) = X3C
      DO 80 J=1,COLS
         B(I,J) = ABS(A(I,J) / X(J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END

*********************************
      SUBROUTINE ALFA(A,B,NEL,ALF)
*********************************
```

```
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
*
* PLY STRESS - STRENGTH,RATIO RISED BY ALFA CALCULATION :
*-------------------------------------------------------
      WRITE (13,10) 'NEL','V1','V2','V3','V6','V5','V4'
      DO 90 I=1,NEL
      DO 80 J=1,COLS
         A(I,J) = B(I,J)**ALF
80    CONTINUE
      WRITE (13,60)I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END

******************************
      SUBROUTINE RELI(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
*
* PLY STERSS TENSOR RELIABILITY CALCULATION (WEIBUL) :
*----------------------------------------------------
      WRITE (13,10) 'NEL','R1','R2','R3','R6','R5','R4'
      DO 90 I=1,NEL
      DO 80 J=1,COLS
         B(I,J) = EXP(-A(I,J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END
*****************************
      SUBROUTINE ELRE(B,NEL)
*****************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 B(ROWS,COLS),ELR(ROWS),STR
*
*ELEMENTS RELIABILITY CALCUL. & STRUCTURE RELIABILITY CALCUL.
*------------------------------------------------------------
      WRITE (13,10) 'NEL','ELM.RE'
      STR = 1.0
      DO 90 I=1,NEL
      ELR(I) = 1.0
      DO 80 J=1,COLS
           ELR(I) = ELR(I) * B(I,J)
80    CONTINUE
      WRITE (5,60) I,ELR(I)
      WRITE (13,60) I,ELR(I)
      STR = STR * ELR(I)
90    CONTINUE
      WRITE (5,70) STR
      WRITE (13,70) STR
10    FORMAT (//,1X,2A10 / 1X,25('-'))
60    FORMAT (/,4X,I6,E11.3)
70    FORMAT (//,1X,'STRUCTURE RELIABILITY = ',E11.3 /1X,40('='))




      RETURN
      END
```

APPENDIX C

POST-PROCESSOR PROGRAMS

We have the state of stress in the spatial locations defined from the FEM (ADINA code). The next steps for evaluating the reliability are:

1. To normalize the size of the element.
2. To perform, per element, the transformation of stresses, read from the FEM output file, to the lamina (composite material) principal directions.
3. To compute the reliabilty based on a specific reliability model.

This process is done by two programs—CLAREA and TRANS3 or TRANS2.

CLAREA is the program which reads in the coordinates as well as the element area defining the nodes. It then computes the element area and the smallest element area.

TRANS3 is the program used for 3-D analysis. It reads in the stress components of each element as well as the element area and the angle theta, coresponding to the angle between the global coordinate system and the layer pricipal coordinate system. It then performs the transformation of stress to the principal direction. In addition, this program calls the subroutine BETA, which in turn calls subroutine ALFA, which in turn calls subroutine RELI, and which finally in turn calls subroutine ELRE.

TRANS2 is the program used for 2-D analysis. It reads in the strain components as well as the modulus of elasticity utilized in the repair or the parent structure, the angle theta, and the element area. It then calculates the stress tensor using the constitutive relation. From this point onward, the program is the same as the TRANS3 program.

These programs are illustrated by solving the verification example, as shown below.

2-D PROBLEM

(Plane Stress

$[90_4]_s$)

```
*        A D I N A - I N    I N P U T    F I L E
*
* THV2D.IN ANALYSIS OF UNISOTROPIC PLATE
*
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL  PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEAD 'THV2D.IN ANALYSIS OF UNISOTROPIC PLATE ( 90,90 DEG )'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM  P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES
ENTRIES NODE  Y    Z
         1   20.    20.
         2  -20.    20.
         3   20.     5.
         4  -20.     5.
         5   20.    -5.
         6  -20.    -5.
         7   20.   -20.
         8  -20.   -20.
         9    0.   -20.
*
*
FIXB 123 / 9
FIXB 13  / 7 8
*
MATERIAL 1 ORTHOTROPIC EA=181.E05 EB=10.3E05 EC=10.3E05,
                       NUAB=0.0159 NUAC=0.0159 NUBC=0.28 GAB=7.17E05
*
EGROUP 1 TWODSOLID STRESS2 TABLES
GSURFACE  1  2  4  3 EL1=1 EL2=1 NODES=9
GSURFACE  5  6  8  7 EL1=1 EL2=1 NODES=9
STRESSTABLE 1 9
EDATA
ENTRIES EL  THICK   BET TABLE
        1   0.1     90   1
        2   0.1     90   1
*
LOADS ELEMENT
   1  2  -3.0E04
*
EGROUP 2 TWODSOLID STRESS2 TABLES
GSURFACE  3  4  6  5 EL1=1 EL2=1 NODES=9
STRESSTABLE 1 9
EDATA
ENTRIES EL  THICK   BET TABLE
        1   0.1     90   1
*
*
VIEW ID=1 XVIEW=1 YVIEW=0 ZVIEW=0
EGZONE NAME=TWODSOLID
   1/2
```

```
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=TWODSOLID NODES=11 ELEMENT=2 BCODE=ALL VIEW=1
*
ADINA
*
END
```

```
S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   1   (2/D CONTINUUM)
                                                                                 (PLANE STRESS)

STRESSES ARE MEASURED IN GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                                  STRESSES / TOTAL STRAINS
 NUMBER      POINT                                    C  O  M  P  O  N  E  N  T  S
              ITB          XX            YY            ZZ            YZ          MAX STRESS      MIN STRESS      ANGLE
                                                                                IN Y-Z PLANE    IN Y-Z PLANE
                                        (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)


      1
              9       0.0000E+00    -0.1116E-11    0.3000E+05    -0.5844E-13     0.3000E+05    -0.9095E-12     -90.00
                     -0.4631E-03    -0.4631E-03    0.1657E-02    -0.2814E-17


      2
              9       0.0000E+00     0.4832E-12    0.3000E+05    -0.1453E-12     0.3000E+05     0.4547E-12     -90.00
                     -0.4631E-03    -0.4631E-03    0.1657E-02    -0.2935E-17
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV2D.IN ANALYSIS OF UNISOTROPIC PLATE ( 90,90 DEG )

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2  (2/D CONTINUUM)
                                                                                 (PLANE STRESS)

STRESSES ARE MEASURED IN GLOBAL COORDINATE SYSTEM

ELEMENT  STRESS TABLE                                STRESSES / TOTAL STRAINS
 NUMBER     POINT                                  C  O  M  P  O  N  E  N  T  S
             ITB          XX             YY             ZZ             YZ          MAX STRESS     MIN STRESS       ANGLE
                                                                                   IN Y-Z PLANE   IN Y-Z PLANE
                                  (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)

      1
             9      0.0000E+00     0.1492E-12     0.3000E+05    -0.1238E-12     0.3000E+05     0.0000E+00      -90.00
                   -0.4631E-03    -0.4631E-03     0.1657E-02    -0.2905E-17
```

2-D PROBLEM

(Plane Stress

$[90_2/75_2]_s$)

*Also includes output of MIC-MAC program showing the laminate stiffness E_{io} (page 2, column w, rows 22-28)

	A	B	C	D	E	F	G	H	I
1	MIC-MAC/IN-PLANE: {[theta/*],...}S					Ply mat:	T3/N52[SI]		
2	[theta]	**-82.5**	**82.5**	**82.5**	**-82.5**	[repeat]	h, *	h,E-3	[Rotate]
3	[*/group]	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	8.0	1.0	**0.00**
4									
5	R/intact	6.08	6.08	6.08	6.08	R/FPF	6.08	safety	**1.50**
6	R/degraded	6.27	6.27	6.27	6.27	R/LPF	6.27	R/ult	6.27
7						R/lim	4.18	R/lim*	4.18
8	{N},MN/m or k/in		<sigma>	<sig>lim	<sig>lim*	<sig>ult	{E°}lim	E^u/E^1	
9	1	**0.00**	0.	0.	0.	0.	10.5	0.436	
10	2	**0.25**	250.	1045.	1045.	1567.	173.4	0.997	
11	6	**0.00**	0.	0.	0.	0.	9.8	0.579	
12									
13		{N} lim	<eps>E-3	<eps>lim	<eps>lim*	<eps>ult	alph o,E-6	beta o	
14	1	0.00	-0.75	-3.14	-3.14	-4.71	21.794	0.581	
15	2	1.04	1.44	6.03	6.03	9.04	-0.278	-0.008	
16	6	0.00	0.00	0.00	0.00	0.00	0.000	0.000	
17									
18		T opr	c,moist	vol/f	Em	Efx	Xm	Xfx	Em/Em°
19	Baseline	22.0	0.005	0.70	3.40	259	40.0	2143	0.30
20	[Modified]	22.0	0.005	0.70	3.40	259	40.0	2143	0.30
21	Mod/Bsln	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22	Mod-Bsln	0.0	0.000	Hot/Wet	3.40	259	40.0	2143	
23	/Q-iso	at limit	at ult						
24	stiffness	2.30	2.30						
25	strength	#REF!	#REF!						
26									
27	Ply data linked to Ply Data File:								
28	T3/N52[SI]	181	10.3	0.28	7.17	3.4	122	160	
29	1500	1500	40	246	68	1.2	22	0.005	
30	-0.5	125	0.7	1.6	0.516	0.5	0.2	0.9	
31	0.02	22.5	0	0.6	0.316	0.004	0.004	2000	
32	69.7	325	0.916	1.56	0	0	0	0	
33									
34									
35									
36									
37									
38									
39									
40									

	R	S	T	U	V	W	X	Y
1	INTACT LAMINATE MODULUS MODULE - elastic and hygrothermal constants							
2								
3	[Angle]	theta/1	theta/2	theta/3	theta/4			
4	[theta]	-82.5	82.5	82.5	-82.5	[REPT]+		
5	[*/grp]	1.0	1.0	1.0	1.0	1		
6	2X,rad	-3E+00	3E+00	3E+00	-3E+00	h+/r+,*		
7	4X,rad	-6E+00	6E+00	6E+00	-6E+00	4		
8								
9	Top z*	1.00	0.75	0.50	0.25			
10	Bott z*	0.75	0.50	0.25	0.00			
11	del(z*)	0.25	0.25	0.25	0.25	h+		
12						1E-03		
13								
14	Stiff	[Q]/1	[Q]/2	[Q]/3	[Q]/4	[A]	[A*]	
15	11	10.63	10.63	10.63	10.63	0.01	8E-03	
16	22	176.25	176.25	176.25	176.25	0.18	1E-01	
17	21=12	5.54	5.54	5.54	5.54	0.01	4E-03	
18	66	9.81	9.81	9.81	9.81	0.01	7E-03	
19	61=16	-1.24	1.24	1.24	-1.24	0.00	3E-04	
20	62=26	-20.95	20.95	20.95	-20.95	0.00	5E-03	
21					|A|	2E-05		
22	Compl	[a],m/GN		[a*]		Ei o ·		
23	11	95.67		1E-01		10.45		
24	22	5.77		6E-03		173.36		
25	21=12	-3.01		-3E-03		0.03		
26	66	101.93		1E-01		9.81		
27	61=16	0.00		0E+00		0.00		
28	62=26	0.00		0E+00		0.00		E,GPa
29								X,MPa
30	Nonmechanical stress(Pa) and strain					V*/iA		rho
31	V*/1A	-2E-01	-2E-01	-2E-01	-2E-01	-1E+00		R=X/|sig|
32	V*/3A	-6E-02	6E-02	6E-02	-6E-02	0E+00		rel rho
33		p^n /T	p^n /c	sig^n /T	sig^n /c	alpha o	beta o	eps/iso
34	1	2E-04	4E+00	2E-04	6E+00	21.794	0.581	rel stiff
35	2	-8E-05	-2E+00	7E-05	2E+00	-0.278	-0.008	spec stiff
36	6	sig^n o	eps^n o	0E+00	0E+00	0.000	0.000	spec R
37	1	8E-03	7E-04	e/x	-2E-06	0.001		nu/iso
38	2	2E-03	-1E-05	e/y	8E-04	-0.001		fn(nu)
39	6	0E+00	0E+00	e/s	0E+00	0.000		
40								

	A	B	C	D	E	F	G	H	I
1	MIC-MAC/IN-PLANE : {[theta/*], . . .}S					Ply mat:	T3/N52[SI]		
2	[theta]	**-82.5**	**82.5**	**82.5**	**-82.5**	[repeat]	h, *	h,E-3	[Rotate]
3	[*/group]	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	8.0	1.0	**-7.50**
4									
5	R/intact	2.86	2.32	2.32	2.86	R/FPF	2.32	safety	**1.50**
6	R/degraded	3.21	3.61	3.61	3.21	R/LPF	3.21	R/ult	3.21
7						R/lim	2.14	R/lim*	2.14
8	{N},MN/m or k/in		<sigma>	<sig>lim	<sig>lim*	<sig>ult	{E°}lim	E^u/E^1	
9	1	**0.00**	0.	0.	0.	0.	10.6	0.438	
10	2	**0.25**	250.	535.	535.	802.	138.7	0.851	
11	6	**0.00**	0.	0.	0.	0.	9.8	0.569	
12									
13		{N} lim	<eps>E-3	<eps>lim	<eps>lim*	<eps>ult	alph o,E-6	beta o	
14	1	0.00	-0.73	-1.56	-1.56	-2.34	21.417	0.571	
15	2	0.53	1.80	3.85	3.85	5.78	0.098	0.002	
16	6	0.00	-2.74	-5.85	-5.85	-8.78	-5.713	-0.152	
17									
18		T opr	c,moist	vol/f	Em	Efx	Xm	Xfx	Em/Em°
19	Baseline	22.0	0.005	0.70	3.40	259	40.0	2143	0.30
20	[Modified]	22.0	0.005	0.70	3.40	259	40.0	2143	0.30
21	Mod/Bsln	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22	Mod-Bsln	0.0	0.000	Hot/Wet	3.40	259	40.0	2143	
23	/Q-iso	at limit	at ult						
24	stiffness	1.36	0.96						
25	strength	*REF!	*REF!						
26									
27	Ply data linked to Ply Data File :								
28	T3/N52[SI]	181	10.3	0.28	7.17	3.4	122	160	
29	1500	1500	40	246	68	1.2	22	0.005	
30	-0.5	125	0.7	1.6	0.516	0.5	0.2	0.9	
31	0.02	22.5	0	0.6	0.316	0.004	0.004	2000	
32	69.7	325	0.916	1.56	0	0	0	0	
33									
34									
35									
36									
37									
38									
39									
40									

	R	S	T	U	V	W	X	Y
1	INTACT LAMINATE MODULUS MODULE - elastic and hygrothermal constants							
2								
3	[Angle]	theta/1	theta/2	theta/3	theta/4			
4	[theta]	90.0	90.0	75.0	75.0	[REPT]+		
5	[*/grp]	1.0	1.0	1.0	1.0	1		
6	2X,rad	3E+00	3E+00	3E+00	3E+00	h+/r+,*		
7	4X,rad	6E+00	6E+00	5E+00	5E+00	4		
8								
9	Top z*	1.00	0.75	0.50	0.25			
10	Bott z*	0.75	0.50	0.25	0.00			
11	del(z*)	0.25	0.25	0.25	0.25	h+		
12						1E-03		
13								
14	Stiff	[Q]/1	[Q]/2	[Q]/3	[Q]/4	[A]	[A*]	
15	11	10.35	10.35	11.98	11.98	0.01	9E-03	
16	22	181.81	181.81	160.47	160.47	0.17	1E-01	
17	21=12	2.90	2.90	12.75	12.75	0.01	7E-03	
18	66	7.17	7.17	17.03	17.03	0.01	1E-02	
19	61=16	0.00	0.00	4.36	4.36	0.00	2E-03	
20	62=26	0.00	0.00	38.50	38.50	0.02	2E-02	
21					|A|	2E-05		
22	Compl	[a],m/GN		[a*]		Ei o		
23	11	94.04		9E-02		10.63		
24	22	7.21		7E-03		138.75		
25	21=12	-2.91		-3E-03		0.03		
26	66	102.30		1E-01		9.78		
27	61=16	-12.32		-1E-02		-0.13		
28	62=26	-10.94		-1E-02		-1.52		E,GPa
29								X,MPa
30	Nonmechanical stress(Pa) and strain					V*/iA		rho
31	V*/1A	-3E-01	-3E-01	-2E-01	-2E-01	-9E-01		R=X/|sig
32	V*/3A	3E-17	3E-17	1E-01	1E-01	3E-01		rel rho
33		p^n /T	p^n /c	sig^n /T	sig^n /c	alpha o	beta o	eps/iso
34	1	2E-04	4E+00	2E-04	6E+00	21.417	0.571	rel stiff
35	2	-8E-05	-2E+00	7E-05	2E+00	0.098	0.002	spec stiff
36	6	sig^n o	eps^n o	-2E-05	-6E-01	-5.713	-0.152	spec R
37	1	8E-03	7E-04	e/x	-2E-06	0.001		nu/iso
38	2	2E-03	6E-07	e/y	8E-04	-0.001		fn(nu)
39	6	-7E-04	-2E-04	e/s	0E+00	0.000		
40								

```
*       A D I N A - I N   I N P U T   F I L E
*
* THV2D.IN ANALYSIS OF UNISOTROPIC PLATE
*
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL  PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEAD 'THV2D.IN ANALYSIS OF UNISOTROPIC PLATE ( 90,75 DEG )'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM  P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES
ENTRIES NODE  Y    Z
         1   20.    20.
         2  -20.    20.
         3   20.     5.
         4  -20.     5.
         5   20.    -5.
         6  -20.    -5.
         7   20.   -20.
         8  -20.   -20.
         9    0.   -20.
*
*
FIXB 123 / 9
FIXB 13  / 7 8
*
MATERIAL 1 ORTHOTROPIC EA=173.36E05 EB=10.45E05 EC=10.3E05,
                       NUAB=0.03 NUAC=0.03 NUBC=0.28 GAB=9.81E05
*
EGROUP 1 TWODSOLID STRESS2 TABLES
GSURFACE  1  2  4  3 EL1=1 EL2=1 NODES=9
GSURFACE  5  6  8  7 EL1=1 EL2=1 NODES=9
STRESSTABLE 1 9
EDATA
ENTRIES EL  THICK   BET TABLE
        1   0.1     82.5   1
        2   0.1     82.5   1
*
LOADS ELEMENT
   1  2  -3.0E04
*
EGROUP 2 TWODSOLID STRESS2 TABLES
GSURFACE  3  4  6  5 EL1=1 EL2=1 NODES=9
STRESSTABLE 1 9
EDATA
ENTRIES EL  THICK   BET TABLE
        1   0.1     82.5   1
*
*
VIEW ID=1 XVIEW=1 YVIEW=0 ZVIEW=0
EGZONE NAME=TWODSOLID
   1/2
```

```
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=TWODSOLID NODES=11 ELEMENT=2 BCODE=ALL VIEW=1
*
ADINA
*
END
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV2D.IN ANALYSIS OF UNISOTROPIC PLATE ( 90,75 DEG )


S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2   (2/D CONTINUUM)
                                                                                 (PLANE STRESS)


STRESSES ARE MEASURED IN GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                                    STRESSES / TOTAL STRAINS
 NUMBER      POINT                                      C  O  M  P  O  N  E  N  T  S
              ITB          XX            YY              ZZ             YZ           MAX STRESS      MIN STRESS      ANGLE
                                                                                     IN Y-Z PLANE    IN Y-Z PLANE
                                  (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)


     1
               9       0.0000E+00    -0.7248E-12    0.3000E+05    -0.2672E-11     0.3000E+05    -0.9095E-12     -90.00
                      -0.9978E-03    -0.8348E-03    0.2164E-02    -0.3294E-02
```

```
S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   1   (2/D CONTINUUM)
                                                                                 (PLANE STRESS)

STRESSES ARE MEASURED IN GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                                STRESSES / TOTAL STRAINS
 NUMBER      POINT                                  C  O  M  P  O  N  E  N  T  S
              ITB          XX            YY            ZZ            YZ          MAX STRESS     MIN STRESS      ANGLE
                                                                                IN Y-Z PLANE   IN Y-Z PLANE
                                  (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)

     1
              9       0.0000E+00    -0.5116E-12    0.3000E+05    -0.1307E-11    0.3000E+05    -0.4547E-12    -90.00
                     -0.9978E-03    -0.8348E-03    0.2164E-02    -0.3294E-02

     2
              9       0.0000E+00    -0.1421E-13    0.3000E+05    -0.2046E-11    0.3000E+05     0.0000E+00    -90.00
                     -0.9978E-03    -0.8348E-03    0.2164E-02    -0.3294E-02
```

3-D PROBLEM

$[90_4]_s$

```
*       A D I N A - I N   I N P U T   F I L E
*
* THV3D.IN EIGHT SYMMETRIC LAYER USING 3-D.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THV3D.IN; ***EIGHT LAYERS SOLUTION  90,90 DEG ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE      X        Y          Z
                          1    -20.    -20.        0.1
                          2     20.    -20.        0.1
                          3    -20.     -5.        0.1
                          4     20.     -5.        0.1
                          5    -20.    -20.        0.
                          6     20.    -20.        0.
                          7    -20.     -5.        0.
                          8     20.     -5.        0.
                          9    -20.      5.        0.1
                         10     20.      5.        0.1
                         11    -20.     20.        0.1
                         12     20.     20.        0.1
                         13    -20.      5.        0.
                         14     20.      5.        0.
                         15    -20.     20.        0.
                         16     20.     20.        0.
                         17      0.     20.        0.1
                         18      0.     20.        0.
                        101      5.      0.        0.
                        102      0.     10.        0.
                        103      5.     10.        0.
                        104     15.      2.68      0.
                        105      7.68   10.        0.
                        106     15.     10.        0.
                        107     15.    -10.        0.
*=====================================================
*NOTE THE MAXES MEANS : 1=90DEG 2=15 3=75 4=45 5=-45
*=====================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                       GAB=7.17E05 7.17E05 7.17E05
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 1  2  4  3  5  6  8  7 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 10 12 11 13 14 16 15 EL1=1 EL2=1 EL3=4 NODES=27
*GVOLUME 1  2  4  3  5  6  8  7 EL1=1 EL2=1 EL3=4 NODES=8
*GVOLUME 9 10 12 11 13 14 16 15 EL1=1 EL2=1 EL3=4 NODES=8
GSURFACE 11 12 16 15 EL1=1 EL2=4 NO=9
LINE STRAIGHT 17 18 EL=4 M=1 NC=ALL
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
```

```
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
                2    1     1
                3    1     1
                4    1     1
                5    1     1
                6    1     1
                7    1     1
                8    1     1
*
LOADS ELEMENT
              1  2  -3.0E04
         TO
              4  2  -3.0E04

*
FIXB 123 LINES / 17 18
FIXB 23 SURFACES /  11 12 16 15
*FIXB 23 LINES / 12 16 / 16 11 / 11 15 / 15 16 .
*
*
EGROUP 2 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 3  4 10  9  7  8 14 13 EL1=1 EL2=1 EL3=4 NODES=27
*GVOLUME 3  4 10  9  7  8 14 13 EL1=1 EL2=1 EL3=4 NODES=8
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
                2    1     1
                3    1     1
                4    1     1
*
*
EGZONE NAME=THREEDSOLID / 1 / 2
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=THREEDSOLID NODES=01 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

```
STRESS CALCULATIONS FOR ELEMENT GROUP   1   (3/D CONTINUUM)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                         STRESSES / TOTAL STRAINS
 NUMBER      POINT                            C O M P O N E N T S
              ITB          XX          YY          ZZ          XY          XZ          YZ

                   (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)

      1
              21   -0.10093E+01  0.29998E+05 -0.24400E+01 -0.48111E-08  0.80322E-11 -0.95407E-01
                   -0.46340E-03  0.16574E-02 -0.46517E-03 -0.67100E-14  0.11203E-16 -0.13306E-06

      2
              21   -0.10087E+01  0.29998E+05 -0.24375E+01 -0.15090E-08  0.17656E-10 -0.31681E-01
                   -0.46340E-03  0.16574E-02 -0.46517E-03 -0.21046E-14  0.24625E-16 -0.44186E-07

      3
              21   -0.10087E+01  0.29998E+05 -0.24375E+01  0.17932E-08  0.14737E-10  0.31681E-01
                   -0.46340E-03  0.16574E-02 -0.46517E-03  0.25010E-14  0.20553E-16  0.44186E-07

      4
              21   -0.10093E+01  0.29998E+05 -0.24400E+01  0.50955E-08  0.24348E-10  0.95407E-01
                   -0.46340E-03  0.16574E-02 -0.46517E-03  0.71067E-14  0.33958E-16  0.13306E-06

      5
              21   -0.34786E+02  0.29969E+05 -0.77132E+02  0.45886E-08  0.15616E-10 -0.33175E+00
                   -0.47544E-03  0.16575E-02 -0.52806E-03  0.63997E-14  0.21780E-16 -0.46270E-06

      6
              21   -0.34784E+02  0.29969E+05 -0.77125E+02  0.55817E-08  0.17885E-10 -0.11038E+00
                   -0.47544E-03  0.16575E-02 -0.52806E-03  0.77847E-14  0.24944E-16 -0.15395E-06

      7
              21   -0.34784E+02  0.29969E+05 -0.77125E+02  0.65747E-08  0.19741E-10  0.11038E+00
                   -0.47544E-03  0.16575E-02 -0.52806E-03  0.91698E-14  0.27532E-16  0.15395E-06

      8
              21   -0.34786E+02  0.29969E+05 -0.77132E+02  0.75678E-08  0.11015E-10  0.33175E+00
                   -0.47544E-03  0.16575E-02 -0.52806E-03  0.10555E-13  0.15363E-16  0.46270E-06
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV3D.IN; ***EIGHT LAYERS SOLUTION  90,90 DEG ***

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2   (3/D CONTINUUM)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                               STRESSES / TOTAL STRAINS
 NUMBER      POINT                                  C  O  M  P  O  N  E  N  T  S
              ITB          XX            YY            ZZ            XY            XZ            YZ

                          (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)


     1
              21     -0.76678E+01   0.29992E+05  -0.14800E+02  -0.10664E-08  -0.69475E-11  -0.27969E+00
                     -0.46641E-03   0.16574E-02  -0.47527E-03  -0.14873E-14  -0.96896E-17  -0.39009E-06


     2
              21     -0.76661E+01   0.29992E+05  -0.14792E+02   0.13895E-08   0.31315E-11  -0.92851E-01
                     -0.46641E-03   0.16574E-02  -0.47526E-03   0.19380E-14   0.43675E-17  -0.12950E-06


     3
              21     -0.76661E+01   0.29992E+05  -0.14792E+02   0.38457E-08   0.23678E-10   0.92851E-01
                     -0.46641E-03   0.16574E-02  -0.47526E-03   0.53636E-14   0.33023E-16   0.12950E-06


     4
              21     -0.76678E+01   0.29992E+05  -0.14800E+02   0.63018E-08   0.12379E-10   0.27969E+0
                     -0.46641E-03   0.16574E-02  -0.47527E-03   0.87891E-14   0.17265E-16   0.39009E-0
```

3-D PROBLEM

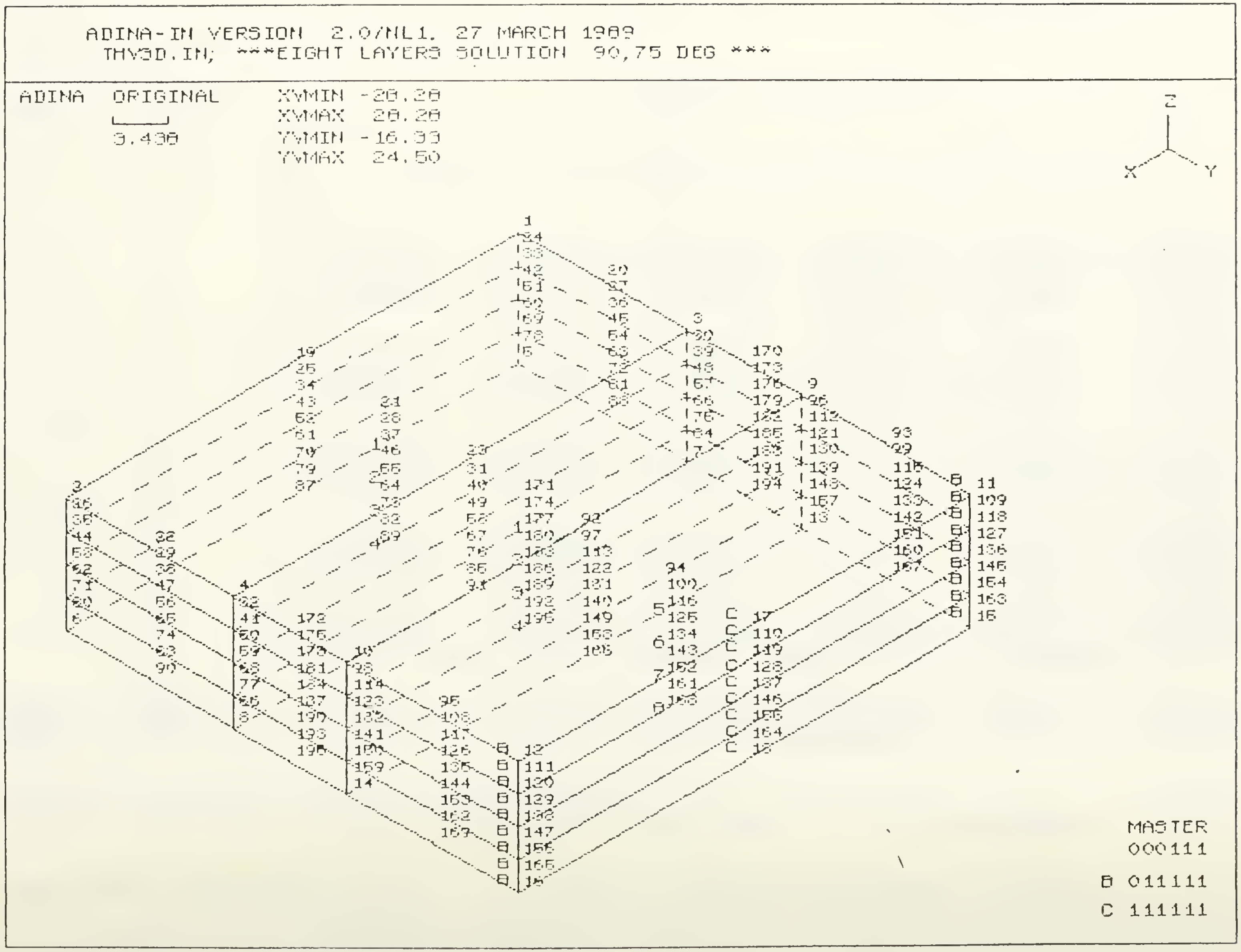
$[90_2/75_2]_s$

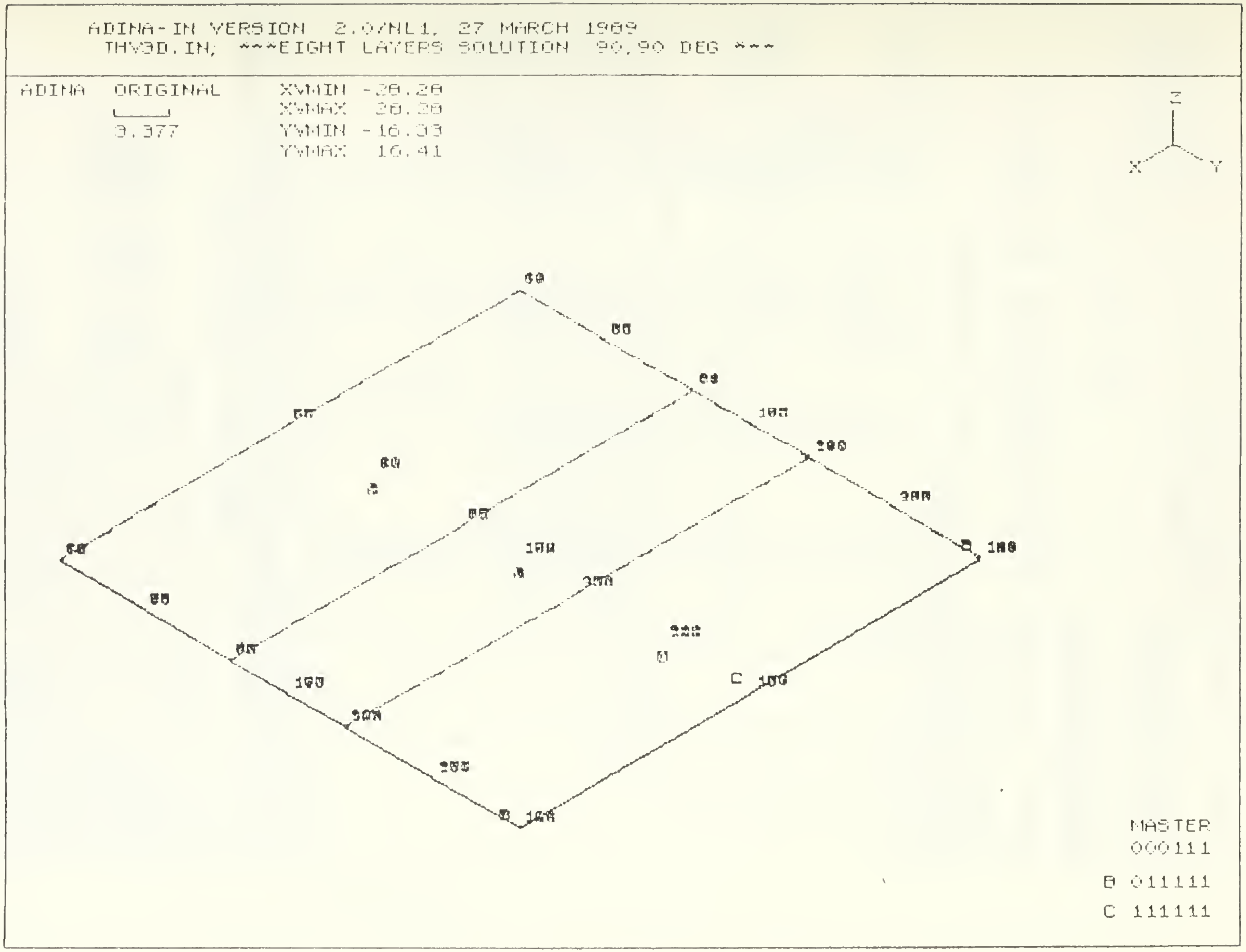
```
*       A D I N A - I N   I N P U T   F I L E
*
* THV3D.IN EIGHT SYMMETRIC LAYER USING 3-D.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THV3D.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE      X         Y          Z
                        1      -20.      -20.        0.1
                        2       20.      -20.        0.1
                        3      -20.       -5.        0.1
                        4       20.       -5.        0.1
                        5      -20.      -20.        0.
                        6       20.      -20.        0.
                        7      -20.       -5.        0.
                        8       20.       -5.        0.
                        9      -20.        5.        0.1
                       10       20.        5.        0.1
                       11      -20.       20.        0.1
                       12       20.       20.        0.1
                       13      -20.        5.        0.
                       14       20.        5.        0.
                       15      -20.       20.        0.
                       16       20.       20.        0.
                       17        0.       20.        0.1
                       18        0.       20.        0.
                      101        5.        0.        0.
                      102        0.       10.        0.
                      103        5.       10.        0.
                      104       15.        2.68      0.
                      105        7.68     10.        0.
                      106       15.       10.        0.
                      107       15.      -10.        0.
*=====================================================
*NOTE THE MAXES MEANS : 1=90DEG 2=15 3=75 4=45 5=-45
*======================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                       GAB=7.17E05 7.17E05 7.17E05
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 1  2  4  3  5  6  8  7 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 10 12 11 13 14 16 15 EL1=1 EL2=1 EL3=4 NODES=27
*GVOLUME 1  2  4  3  5  6  8  7 EL1=1 EL2=1 EL3=4 NODES=8
*GVOLUME 9 10 12 11 13 14 16 15 EL1=1 EL2=1 EL3=4 NODES=8
GSURFACE 11 12 16 15 EL1=1 EL2=4 NO=9
LINE STRAIGHT 17 18 EL=4 M=1 NC=ALL
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
```

```
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
                2    1     3
                3    1     3
                4    1     1
                5    1     1
                6    1     3
                7    1     3
                8    1     1
*
LOADS ELEMENT
              1  2  -3.0E04
         TO
              4  2  -3.0E04

*
FIXB 123 LINES / 17 18
FIXB 23 SURFACES /  11 12 16 15
*FIXB 23 LINES / 12 16 / 16 11 / 11 15 / 15 16
*
*
EGROUP 2 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 3  4 10  9  7  8 14 13 EL1=1 EL2=1 EL3=4 NODES=27
*GVOLUME 3  4 10  9  7  8 14 13 EL1=1 EL2=1 EL3=4 NODES=8
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
                2    1     3
                3    1     3
                4    1     1
*
*
EGZONE NAME=THREEDSOLID / 1 / 2
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=THREEDSOLID NODES=01 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV3D.IN; ***EIGHT LAYERS SOLUTION  90.75 DEG ***

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   1   (3/D CONTINUUM)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                               STRESSES / TOTAL STRAINS
 NUMBER       POINT                                 C O M P O N E N T S
               ITB            XX            YY            ZZ            XY            XZ            YZ

                             (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)

      1
               21      -0.27944E+03   0.39058E+05  -0.28567E+01  -0.23544E+04   0.25365E+01  -0.98306E+01
                       -0.87345E-03   0.21622E-02  -0.52974E-03  -0.32836E-02   0.35377E-05  -0.13711E-04

      2
               21       0.27722E+03   0.20938E+05  -0.26843E+01   0.23542E+04   0.25376E+01  -0.97638E+01
                       -0.87346E-03   0.21624E-02  -0.45432E-03  -0.32837E-02   0.35392E-05  -0.13618E-04

      3
               21       0.27722E+03   0.20938E+05  -0.26843E+01   0.23542E+04  -0.25376E+01   0.97638E+01
                       -0.87346E-03   0.21624E-02  -0.45432E-03  -0.32837E-02  -0.35392E-05   0.13618E-04

      4
               21      -0.27944E+03   0.39058E+05  -0.28567E+01  -0.23544E+04  -0.25365E+01   0.98306E+01
                       -0.87345E-03   0.21622E-02  -0.52974E-03  -0.32836E-02  -0.35377E-05   0.13711E-04

      5
               21      -0.31638E+03   0.39029E+05  -0.88118E+02  -0.23529E+04   0.74178E-01  -0.56600E+00
                       -0.88570E-03   0.21626E-02  -0.60204E-03  -0.32816E-02   0.10346E-06  -0.78941E-06

      6
               21       0.24255E+03   0.20907E+05  -0.75362E+02   0.23517E+04   0.74248E-01  -0.33196E+00
                       -0.88570E-03   0.21626E-02  -0.51537E-03  -0.32816E-02   0.10355E-06  -0.46298E-06

      7
               21       0.24255E+03   0.20907E+05  -0.75362E+02   0.23517E+04  -0.74248E-01   0.33196E+00
                       -0.88570E-03   0.21626E-02  -0.51537E-03  -0.32816E-02  -0.10355E-06   0.46298E-06

      8
               21      -0.31638E+03   0.39029E+05  -0.88118E+02  -0.23529E+04  -0.74178E-01   0.56600E+00
                       -0.88570E-03   0.21626E-02  -0.60204E-03  -0.32816E-02  -0.10346E-06   0.78941E-06
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV3D.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2   (3/D CONTINUUM)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                              STRESSES / TOTAL STRAINS
 NUMBER      POINT                                C O M P O N E N T S
              ITB         XX            YY            ZZ            XY            XZ            YZ

                                (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)


     1
              21     -0.28716E+03  0.39052E+05  -0.16909E+02  -0.23539E+04  0.49368E+00  -0.21583E+01
                     -0.87704E-03  0.21623E-02  -0.54119E-03  -0.32829E-02  0.68853E-06  -0.30102E-05


     2
              21      0.26967E+03  0.20931E+05  -0.14558E+02   0.23533E+04  0.49418E+00  -0.19611E+01
                     -0.87704E-03  0.21623E-02  -0.46380E-03  -0.32830E-02  0.68923E-06  -0.27352E-05


     3
              21      0.26967E+03  0.20931E+05  -0.14558E+02   0.23533E+04 -0.49418E+00   0.19611E+01
                     -0.87704E-03  0.21623E-02  -0.46380E-03  -0.32830E-02 -0.68923E-06   0.27352E-05


     4
              21     -0.28716E+03  0.39052E+05  -0.16909E+02  -0.23539E+04 -0.49368E+00   0.21583E+01
                     -0.87704E-03  0.21623E-02  -0.54119E-03  -0.32829E-02 -0.68853E-06   0.30102E-05
```


ADINA-IN VERSION 2.0/NL1, 27 MARCH 1989
THY3D.IN; ***EIGHT LAYERS SOLUTION 90,75 DEG ***
ADINA ORIGINAL
3.438
XVMIN -28.28
XVMAX 28.28
YVMIN -16.33
YVMAX 24.50
Z
X
Y
MASTER
000111
B 011111
C 111111


ADINA-IN VERSION 2.0/NL1, 27 MARCH 1989
THV3D.IN; ***EIGHT LAYERS SOLUTION 90,90 DEG ***
ADINA ORIGINAL
3.377
XVMIN -28.28
XVMAX 28.28
YVMIN -16.33
YVMAX 16.41
Z
X
Y
C 100
MASTER
000111
B 011111
C 111111

```
*       A D I N A - I N   I N P U T   F I L E
*
* THV3D.IN EIGHT SYMMETRIC LAYER USING 3-D.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THV3D.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE      X        Y          Z
                         1     -20.     -20.        0.1E2
                         2      20.     -20.        0.1E2
                         3     -20.      -5.        0.1E2
                         4      20.      -5.        0.1E2
                         5     -20.     -20.        0.
                         6      20.     -20.        0.
                         7     -20.      -5.        0.
                         8      20.      -5.        0.
                         9     -20.       5.        0.1E2
                        10      20.       5.        0.1E2
                        11     -20.      20.        0.1E2
                        12      20.      20.        0.1E2
                        13     -20.       5.        0.
                        14      20.       5.        0.
                        15     -20.      20.        0.
                        16      20.      20.        0.
                        17       0.      20.        0.1E2
                        18       0.      20.        0.
                       101       5.       0.        0.
                       102       0.      10.        0.
                       103       5.      10.        0.
                       104      15.       2.68      0.
                       105       7.68    10.        0.
                       106      15.      10.        0.
                       107      15.     -10.        0.
*=====================================================
*NOTE THE MAXES MEANS : 1=90DEG 2=15 3=75 4=45 5=-45
*======================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                        GAB=7.17E05 7.17E05 7.17E05
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 1  2  4  3  5  6  8  7 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 10 12 11 13 14 16 15 EL1=1 EL2=1 EL3=4 NODES=27
*GVOLUME 1  2  4  3  5  6  8  7 EL1=1 EL2=1 EL3=4 NODES=8
*GVOLUME 9 10 12 11 13 14 16 15 EL1=1 EL2=1 EL3=4 NODES=8
GSURFACE 11 12 16 15 EL1=1 EL2=4 NO=9
LINE STRAIGHT 17 18 EL=4 M=1 NC=ALL
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
```

```
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
                2    1     3
                3    1     3
                4    1     1
                5    1     1
                6    1     3
                7    1     3
                8    1     1
*
LOADS ELEMENT
              1  2  -3.0E04
         TO
              4  2  -3.0E04

*
FIXB 123 LINES / 17 18
FIXB 23 SURFACES /  11 12 16 15
*FIXB 23 LINES / 12 16 / 16 11 / 11 15 / 15 16.
*
*
EGROUP 2 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 3  4 10  9  7  8 14 13 EL1=1 EL2=1 EL3=4 NODES=27
*GVOLUME 3  4 10  9  7  8 14 13 EL1=1 EL2=1 EL3=4 NODES=8
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
                2    1     3
                3    1     3
                4    1     1
*
*
EGZONE NAME=THREEDSOLID / 1 / 2
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=THREEDSOLID NODES=01 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

```
S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   1   (3/D CONTINUUM)

(GROUP 1 REPRESENTS THE PARENT STRUCTURE)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                               STRESSES / TOTAL STRAINS
 NUMBER      POINT                                  C O M P O N E N T S
              ITB            XX           YY           ZZ           XY           XZ           YZ

                            (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)


    1
              21       -0.27944E+03  0.39058E+05 -0.28567E+01 -0.23544E+04  0.25365E+01 -0.98306E+01
                       -0.87345E-03  0.21622E-02 -0.52974E-03 -0.32836E-02  0.35377E-05 -0.13711E-04


    2
              21        0.27722E+03  0.20938E+05 -0.26843E+01  0.23542E+04  0.25376E+01 -0.97638E+01
                       -0.87346E-03  0.21624E-02 -0.45432E-03 -0.32837E-02  0.35392E-05 -0.13618E-04


    3
              21        0.27722E+03  0.20938E+05 -0.26843E+01  0.23542E+04 -0.25376E+01  0.97638E+01
                       -0.87346E-03  0.21624E-02 -0.45432E-03 -0.32837E-02 -0.35392E-05  0.13618E-04


    4
              21       -0.27944E+03  0.39058E+05 -0.28567E+01 -0.23544E+04 -0.25365E+01  0.98306E+01
                       -0.87345E-03  0.21622E-02 -0.52974E-03 -0.32836E-02 -0.35377E-05  0.13711E-04


    5
              21       -0.31638E+03  0.39029E+05 -0.88118E+02 -0.23529E+04  0.74178E-01 -0.56600E+00
                       -0.88570E-03  0.21626E-02 -0.60204E-03 -0.32816E-02  0.10346E-06 -0.78941E-06


    6
              21        0.24255E+03  0.20907E+05 -0.75362E+02  0.23517E+04  0.74248E-01 -0.33196E+00
                       -0.88570E-03  0.21626E-02 -0.51537E-03 -0.32816E-02  0.10355E-06 -0.46298E-06


    7
              21        0.24255E+03  0.20907E+05 -0.75362E+02  0.23517E+04 -0.74248E-01  0.33196E+00
                       -0.88570E-03  0.21626E-02 -0.51537E-03 -0.32816E-02 -0.10355E-06  0.46298E-06


    8
              21       -0.31638E+03  0.39029E+05 -0.88118E+02 -0.23529E+04 -0.74178E-01  0.56600E+00
                       -0.88570E-03  0.21626E-02 -0.60204E-03 -0.32816E-02 -0.10346E-06  0.78941E-06
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV3D.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2   (3/D CONTINUUM)

(GROUP 2 REPRESENTS THE PATCH REPAIR)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                                  STRESSES / TOTAL STRAINS
NUMBER       POINT                                    C O M P O N E N T S
              ITB           XX            YY            ZZ            XY            XZ            YZ

                                 (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)

      1
              21      -0.28716E+03   0.39052E+05  -0.16909E+02  -0.23539E+04   0.49368E+00  -0.21583E+01
                      -0.87704E-03   0.21623E-02  -0.54119E-03  -0.32829E-02   0.68853E-06  -0.30102E-05

      2
              21       0.26967E+03   0.20931E+05  -0.14558E+02   0.23533E+04   0.49418E+00  -0.19611E+01
                      -0.87704E-03   0.21623E-02  -0.46380E-03  -0.32830E-02   0.68923E-06  -0.27352E-05

      3
              21       0.26967E+03   0.20931E+05  -0.14558E+02   0.23533E+04  -0.49418E+00   0.19611E+01
                      -0.87704E-03   0.21623E-02  -0.46380E-03  -0.32830E-02  -0.68923E-06   0.27352E-05

      4
              21      -0.28716E+03   0.39052E+05  -0.16909E+02  -0.23539E+04  -0.49368E+00   0.21583E+01
                      -0.87704E-03   0.21623E-02  -0.54119E-03  -0.32829E-02  -0.68853E-06   0.30102E-05
```

THV3D.NO : INPUT NODE FILE FOR COORDINATES:

```
 1   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.10000E+00  0  0
 2   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.10000E+00  0  0
 3   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.10000E+00  0  0
 4   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.10000E+00  0  0
 5   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.00000E+00  0  0
 6   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.00000E+00  0  0
 7   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.00000E+00  0  0
 8   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.00000E+00  0  0
 9   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.10000E+00  0  0
10   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.10000E+00  0  0
11   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.10000E+00  0  0
12   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.10000E+00  0  0
13   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.00000E+00  0  0
14   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.00000E+00  0  0
15   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.00000E+00  0  0
16   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.00000E+00  0  0
17   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.10000E+00  0  0
18   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.00000E+00  0  0
19   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.10000E+00  0  0
20   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.10000E+00  0  0
21   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.12500E+02  0.10000E+00  0  0
22   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.10000E+00  0  0
23   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.10000E+00  0  0
24   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.87500E-01  0  0
25   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.87500E-01  0  0
26   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.87500E-01  0  0
27   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.87500E-01  0  0
28   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20820E-16 -0.12500E+02  0.87500E-01  0  0
29   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.87500E-01  0  0
30   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.87500E-01  0  0
31   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.87500E-01  0  0
32   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.87500E-01  0  0
33   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.75000E-01  0  0
34   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.75000E-01  0  0
35   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.75000E-01  0  0
36   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.75000E-01  0  0
37   0  0  0  1  1  1  1  1  1  1  1  1  1   0.13878E-16 -0.12500E+02  0.75000E-01  0  0
38   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.75000E-01  0  0
39   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.75000E-01  0  0
40   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.75000E-01  0  0
41   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.75000E-01  0  0
42   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.62500E-01  0  0
43   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.62500E-01  0  0
44   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.62500E-01  0  0
45   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.62500E-01  0  0
46   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.12500E+02  0.62500E-01  0  0
47   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.62500E-01  0  0
48   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.62500E-01  0  0
49   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.62500E-01  0  0
50   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.62500E-01  0  0
51   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.50000E-01  0  0
52   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.50000E-01  0  0
53   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.50000E-01  0  0
```

```
 55   0  0  0  1  1  1  1  1  1  1  1  1  1   0.55511E-16 -0.12500E+02  0.50000E-01  0  0
 56   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.50000E-01  0  0
 57   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.50000E-01  0  0
 58   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.50000E-01  0  0
 59   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.50000E-01  0  0
 60   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.37500E-01  0  0
 61   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.37500E-01  0  0
 62   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.37500E-01  0  0
 63   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.37500E-01  0  0
 64   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.12500E+02  0.37500E-01  0  0
 65   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.37500E-01  0  0
 66   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.37500E-01  0  0
 67   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.37500E-01  0  0
 68   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.37500E-01  0  0
 69   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.25000E-01  0  0
 70   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.25000E-01  0  0
 71   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.25000E-01  0  0
 72   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.25000E-01  0  0
 73   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.12500E+02  0.25000E-01  0  0
 74   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.25000E-01  0  0
 75   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.25000E-01  0  0
 76   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.25000E-01  0  0
 77   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.25000E-01  0  0
 78   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.20000E+02  0.12500E-01  0  0
 79   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.12500E-01  0  0
 80   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20000E+02  0.12500E-01  0  0
 81   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.12500E-01  0  0
 82   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.12500E+02  0.12500E-01  0  0
 83   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.12500E-01  0  0
 84   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.50000E+01  0.12500E-01  0  0
 85   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.12500E-01  0  0
 86   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.50000E+01  0.12500E-01  0  0
 87   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.20000E+02  0.00000E+00  0  0
 88   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02 -0.12500E+02  0.00000E+00  0  0
 89   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.12500E+02  0.00000E+00  0  0
 90   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.12500E+02  0.00000E+00  0  0
 91   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00 -0.50000E+01  0.00000E+00  0  0
 92   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.10000E+00  0  0
 93   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.10000E+00  0  0
 94   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.12500E+02  0.10000E+00  0  0
 95   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.10000E+00  0  0
 96   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.87500E-01  0  0
 97   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.87500E-01  0  0
 98   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.87500E-01  0  0
 99   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.87500E-01  0  0
100   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20820E-16  0.12500E+02  0.87500E-01  0  0
101   1  1  1  1  1  1  1  1  1  1  1  1  1   0.50000E+01  0.00000E+00  0.00000E+00  0  0
102   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.10000E+02  0.00000E+00  0  0
103   1  1  1  1  1  1  1  1  1  1  1  1  1   0.50000E+01  0.10000E+02  0.00000E+00  0  0
104   1  1  1  1  1  1  1  1  1  1  1  1  1   0.15000E+02  0.26800E+01  0.00000E+00  0  0
105   1  1  1  1  1  1  1  1  1  1  1  1  1   0.76800E+01  0.10000E+02  0.00000E+00  0  0
106   1  1  1  1  1  1  1  1  1  1  1  1  1   0.15000E+02  0.10000E+02  0.00000E+00  0  0
107   1  1  1  1  1  1  1  1  1  1  1  1  1   0.15000E+02 -0.10000E+02  0.00000E+00  0  0
108   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.87500E-01  0  0
109   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.87500E-01  0  0
110   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.87500E-01  0  0
111   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.87500E-01  0  0
112   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.75000E-01  0  0
113   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.75000E-01  0  0
114   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.75000E-01  0  0
```

```
115   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.75000E-01  0  0
116   0  0  0  1  1  1  1  1  1  1  1  1  1   0.13878E-16  0.12500E+02  0.75000E-01  0  0
117   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.75000E-01  0  0
118   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.75000E-01  0  0
119   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.75000E-01  0  0
120   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.75000E-01  0  0
121   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.62500E-01  0  0
122   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.62500E-01  0  0
123   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.62500E-01  0  0
124   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.62500E-01  0  0
125   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.12500E+02  0.62500E-01  0  0
126   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.62500E-01  0  0
127   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.62500E-01  0  0
128   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.62500E-01  0  0
129   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.62500E-01  0  0
130   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.50000E-01  0  0
131   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.50000E-01  0  0
132   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.50000E-01  0  0
133   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.50000E-01  0  0
134   0  0  0  1  1  1  1  1  1  1  1  1  1   0.55511E-16  0.12500E+02  0.50000E-01  0  0
135   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.50000E-01  0  0
136   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.50000E-01  0  0
137   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.50000E-01  0  0
138   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.50000E-01  0  0
139   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.37500E-01  0  0
140   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.37500E-01  0  0
141   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.37500E-01  0  0
142   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.37500E-01  0  0
143   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.12500E+02  0.37500E-01  0  0
144   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.37500E-01  0  0
145   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.37500E-01  0  0
146   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.37500E-01  0  0
147   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.37500E-01  0  0
148   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.25000E-01  0  0
149   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.25000E-01  0  0
150   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.25000E-01  0  0
151   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.25000E-01  0  0
152   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.12500E+02  0.25000E-01  0  0
153   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.25000E-01  0  0
154   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.25000E-01  0  0
155   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.25000E-01  0  0
156   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.25000E-01  0  0
157   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.50000E+01  0.12500E-01  0  0
158   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.12500E-01  0  0
159   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.50000E+01  0.12500E-01  0  0
160   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.12500E-01  0  0
161   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.12500E+02  0.12500E-01  0  0
162   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.12500E-01  0  0
163   0  1  1  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.20000E+02  0.12500E-01  0  0
164   1  1  1  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.20000E+02  0.12500E-01  0  0
165   0  1  1  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.20000E+02  0.12500E-01  0  0
166   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.50000E+01  0.00000E+00  0  0
167   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.12500E+02  0.00000E+00  0  0
168   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.12500E+02  0.00000E+00  0  0
169   0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.12500E+02  0.00000E+00  0  0
170   0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.10000E+00  0  0
171   0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.00000E+00  0.10000E+00  0  0
```

```
175    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02 -0.20820E-16  0.87500E-01  0  0
176    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.13878E-16  0.75000E-01  0  0
177    0  0  0  1  1  1  1  1  1  1  1  1  1   0.13878E-16  0.34694E-17  0.75000E-01  0  0
178    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.13878E-16  0.75000E-01  0  0
179    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.62500E-01  0  0
180    0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.00000E+00  0.62500E-01  0  0
181    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.00000E+00  0.62500E-01  0  0
182    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.50000E-01  0  0
183    0  0  0  1  1  1  1  1  1  1  1  1  1   0.55511E-16  0.00000E+00  0.50000E-01  0  0
184    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.00000E+00  0.50000E-01  0  0
185    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.37500E-01  0  0
186    0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.00000E+00  0.37500E-01  0  0
187    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.00000E+00  0.37500E-01  0  0
188    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.25000E-01  0  0
189    0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.00000E+00  0.25000E-01  0  0
190    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.00000E+00  0.25000E-01  0  0
191    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.12500E-01  0  0
192    0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.00000E+00  0.12500E-01  0  0
193    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.00000E+00  0.12500E-01  0  0
194    0  0  0  1  1  1  1  1  1  1  1  1  1  -0.20000E+02  0.00000E+00  0.00000E+00  0  0
195    0  0  0  1  1  1  1  1  1  1  1  1  1   0.00000E+00  0.00000E+00  0.00000E+00  0  0
196    0  0  0  1  1  1  1  1  1  1  1  1  1   0.20000E+02  0.00000E+00  0.00000E+00  0  0
```

```
THV3D.EL :
----------

E L E M E N T   I N F O R M A T I O N   F O R   P A R E N T   S T R U C T U R E

   M IELD IELX  IPS  ISV MTYP MAXES   KG    ETIME      ETIME2    INTLOC NODE 1 NODE 2 NODE 3 NODE 4 NODE 5 NODE 6 NODE 7 NODE


   1   27   27   -1    1    1    1    1  0.0000E+00  0.0000E+00     0      1      2      4      3     33     35     41
   2   27   27   -1    1    1    3    1  0.0000E+00  0.0000E+00     0     33     35     41     39     51     53     59
   3   27   27   -1    1    1    3    1  0.0000E+00  0.0000E+00     0     51     53     59     57     69     71     77
   4   27   27   -1    1    1    1    1  0.0000E+00  0.0000E+00     0     69     71     77     75      5      6      8
   5   27   27   -1    1    1    1    1  0.0000E+00  0.0000E+00     0      9     10     12     11    112    114    120
   6   27   27   -1    1    1    3    1  0.0000E+00  0.0000E+00     0    112    114    120    118    130    132    138
   7   27   27   -1    1    1    3    1  0.0000E+00  0.0000E+00     0    130    132    138    136    148    150    156
   8   27   27   -1    1    1    1    1  0.0000E+00  0.0000E+00     0    148    150    156    154     13     14     16

E L E M E N T   I N F O R M A T I O N   F O R   R E P A I R

   1   27   27   -1    1    1    1    1  0.0000E+00  0.0000E+00     0      3      4     10      9     39     41    114
   2   27   27   -1    1    1    3    1  0.0000E+00  0.0000E+00     0     39     41    114    112     57     59    132
   3   27   27   -1    1    1    3    1  0.0000E+00  0.0000E+00     0     57     59    132    130     75     77    150
   4   27   27   -1    1    1    1    1  0.0000E+00  0.0000E+00     0     75     77    150    148      7      8     14
```

```
THV3D.STR :
---------

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   1   (3/D CONTINUUM)

(GROUP 1 REPRESENTS THE PARENT STRUCTURE)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                                STRESSES / TOTAL STRAINS
 NUMBER       POINT                                 C O M P O N E N T S
               ITB            XX           YY           ZZ           XY           XZ           YZ

                           (STRAINS ARE ONLY PRINTED WHEN ELEMENT;FLAG (IPS) SO INDICATES)

      1
               21     -0.27944E+03  0.39058E+05 -0.28567E+01 -0.23544E+04  0.25365E+01 -0.98306E+01
                      -0.87345E-03  0.21622E-02 -0.52974E-03 -0.32836E-02  0.35377E-05 -0.13711E-04

      2
               21      0.27722E+03  0.20938E+05 -0.26843E+01  0.23542E+04  0.25376E+01 -0.97638E+01
                      -0.87346E-03  0.21624E-02 -0.45432E-03 -0.32837E-02  0.35392E-05 -0.13618E-04

      3
               21      0.27722E+03  0.20938E+05 -0.26843E+01  0.23542E+04 -0.25376E+01  0.97638E+01
                      -0.87346E-03  0.21624E-02 -0.45432E-03 -0.32837E-02 -0.35392E-05  0.13618E-04

      4
               21     -0.27944E+03  0.39058E+05 -0.28567E+01 -0.23544E+04 -0.25365E+01  0.98306E+01
                      -0.87345E-03  0.21622E-02 -0.52974E-03 -0.32836E-02 -0.35377E-05  0.13711E-04

      5
               21     -0.31638E+03  0.39029E+05 -0.88118E+02 -0.23529E+04  0.74178E-01 -0.56600E+00
                      -0.88570E-03  0.21626E-02 -0.60204E-03 -0.32816E-02  0.10346E-06 -0.78941E-06

      6
               21      0.24255E+03  0.20907E+05 -0.75362E+02  0.23517E+04  0.74248E-01 -0.33196E+00
                      -0.88570E-03  0.21626E-02 -0.51537E-03 -0.32816E-02  0.10355E-06 -0.46298E-06

      7
               21      0.24255E+03  0.20907E+05 -0.75362E+02  0.23517E+04 -0.74248E-01  0.33196E+00
                      -0.88570E-03  0.21626E-02 -0.51537E-03 -0.32816E-02 -0.10355E-06  0.46298E-06

      8
               21     -0.31638E+03  0.39029E+05 -0.88118E+02 -0.23529E+04 -0.74178E-01  0.56600E+00
                      -0.88570E-03  0.21626E-02 -0.60204E-03 -0.32816E-02 -0.10346E-06  0.78941E-06
```

```
PROGRAM ADINA - VERSION ADINA 5.0/NL2          THV3D.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2   (3/D CONTINUUM)

(GROUP 2 REPRESENTS THE PATCH REPAIR)

STRESSES ARE CALCULATED IN THE GLOBAL COORDINATE SYSTEM

ELEMENT   STRESS TABLE                           STRESSES / TOTAL STRAINS
 NUMBER      POINT                           C  O  M  P  O  N  E  N  T  S
              ITB          XX            YY            ZZ            XY            XZ            YZ

                       (STRAINS ARE ONLY PRINTED WHEN ELEMENT FLAG (IPS) SO INDICATES)

      1
              21     -0.28716E+03   0.39052E+05  -0.16909E+02  -0.23539E+04   0.49368E+00  -0.21583E+01
                     -0.87704E-03   0.21623E-02  -0.54119E-03  -0.32829E-02   0.68853E-06  -0.30102E-05

      2
              21      0.26967E+03   0.20931E+05  -0.14558E+02   0.23533E+04   0.49418E+00  -0.19611E+01
                     -0.87704E-03   0.21623E-02  -0.46380E-03  -0.32830E-02   0.68923E-06  -0.27352E-05

      3
              21      0.26967E+03   0.20931E+05  -0.14558E+02   0.23533E+04  -0.49418E+00   0.19611E+01
                     -0.87704E-03   0.21623E-02  -0.46380E-03  -0.32830E-02  -0.68923E-06   0.27352E-05

      4
              21     -0.28716E+03   0.39052E+05  -0.16909E+02  -0.23539E+04  -0.49368E+00   0.21583E+01
                     -0.87704E-03   0.21623E-02  -0.54119E-03  -0.32829E-02  -0.68853E-06   0.30102E-05
```

```
**************************************************
      PROGRAM CLAREA
**************************************************
C
C     THIS PROGRAM WHICH READS THE NODAL POINT COORDINATE, AS WELL READS
C     THE NODES DEFINING THE ELEMENT AREA, AND READS THE ANGLE OF ELEMENT
C     ORIENTATION  FROM FILES CREATED FROM THE MAIN ADINA OUTPUT FILE.
C     IN ADDITION THIS PROGRAM CALCULATES THE MINIMUM AREA.
C     BEFORE RUNING THE PROGRAM VERIFY THE # OF ELEMENT(NEL), THE #OF NODES
C     (NNOD).
      INTEGER     IEL,NEL,NNOD,INOD
      PARAMETER  (NEL=12,NNOD=196)
      INTEGER     INODE(NEL,4),NODE(4)
      REAL        COOR(NNOD,20),AREA1,AREA2,AREA(NEL)
      REAL        B1,B2,C1,C2,BB1,BB2,CC1,CC2
      REAL        X(4),Y(4)
      CHARACTER*10 FNAME1,FNAME2,FNOUT
*
      WRITE (5,*) 'ENTER FILES NAMES FROM ADINA OUTPUT FILE?'
      WRITE (5,*) 'NODAL POINT DATA FN ?'
      READ (5,'(A)') FNAME1
      OPEN (UNIT=16,FILE=FNAME1,STATUS='OLD')
      WRITE (5,*) 'NODAL POINT DATA FN : ',FNAME1
      WRITE (3,*) 'NODAL POINT DATA FN : ',FNAME1
      WRITE (5,*) 'ELEMENTS NODES FN ?'
      READ (5,'(A)') FNAME2
      OPEN (UNIT=15,FILE=FNAME2,STATUS='OLD')
      WRITE (5,*) 'ELEMENTS NODES  FN : ',FNAME2
      WRITE (3,*) 'ELEMENTS NODES  FN : ',FNAME2
      WRITE (5,*) 'ENTER THE NAME OF ELEMENTS AREAS FILE ?'
      READ (5,'(A)') FNOUT
      OPEN (UNIT=13,FILE=FNOUT,STATUS='NEW')
      WRITE (5,*) 'AREAS OF ELEMENTS FILE : ',FNOUT
      WRITE (3,*) 'AREAS OF ELEMENTS FILE : ',FNOUT
*
* DIFINING X,Y COORDINATES FROM NODAL POINT DATA FILE
*-----------------------------------------------------
*      WRITE (5,30) 'NNOD','XCOOR','YCOOR'
*      WRITE (3,30) 'NNOD','XCOOR','YCOOR'
      DO 50 I=1,NNOD
            READ (16,*) INOD,II2,II3,II4,II5,II6,II7,II8,II9,II10,II11,
     &                  II12,II13,II14,COOR(I,1),COOR(I,2),A17,II18,II19
*           WRITE (5,40)I,COOR(I,1),COOR(I,2)
*           WRITE (3,40)I,COOR(I,1),COOR(I,2)
50    CONTINUE
*
* DIFINING ELEMENT'S NODES FROM ELEM.NODES FN.
*--------------------------------------------
      WRITE (5,10) 'NEL', 'NODE1','NODE2','NODE3','NODE4'
      WRITE (3,10) 'NEL', 'NODE1','NODE2','NODE3','NODE4'
      AMIN=2000.0
      DO 100 IEL=1,NEL
      READ (15,*) IIEL,I2,I3,I4,I5,I6,I7,I8,A9,A10,I11,INODE(IEL,1),
     &     INODE(IEL,2),INODE(IEL,3),INODE(IEL,4),I16,I17,I18,I19
      WRITE(5,20) IIEL,INODE(IEL,1),INODE(IEL,2),INODE(IEL,3),
     &            INODE(IEL,4)
      WRITE(3,20) IIEL,INODE(IEL,1),INODE(IEL,2),INODE(IEL,3),
     &            INODE(IEL,4)
            NODE(1) = INODE(IEL,1)
            NODE(2) = INODE(IEL,2)
```

```
              NODE(3) = INODE(IEL,3)
              NODE(4) = INODE(IEL,4)
*
* DIFINING THE X,Y COORD. TO NODE(1) - NODE(4)
*-----------------------------------------------------
      WRITE (5,30) 'NNOD','XCOOR','YCOOR'
      WRITE (3,30) 'NNOD','XCOOR','YCOOR'
      DO 80 J=1,4
      DO 70 I=1,NNOD
         IF (I.EQ.NODE(J)) THEN
                 X(J) = COOR(I,1)
                 Y(J) = COOR(I,2)
            WRITE (5,40)I,X(J),Y(J)
            WRITE (3,40)I,X(J),Y(J)
          GO TO 80
         END IF
70    CONTINUE
80    CONTINUE
*
* ELEMENTS AREA CALCULATION.
*--------------------------
      B1 = Y(3) - Y(4)
      B2 = Y(4) - Y(2)
      C1 = X(4) - X(3)
      C2 = X(3) - X(2)
      BB1 = Y(4) - Y(1)
      BB2 = Y(1) - Y(2)
      CC1 = X(1) - X(4)
      CC2 = X(2) - X(1)
      AREA1 = ABS(C2*B1 - C1*B2) / 2.0
      AREA2 = ABS(CC2*BB1 - CC1*BB2) / 2.0
      AREA(IEL) = AREA1 +AREA2
      AEL=AREA(IEL)
      AMIN = MIN(AMIN,AEL)
      WRITE (5,90) IIEL,AREA(IEL),AMIN
      WRITE (3,90) IIEL,AREA(IEL),AMIN
100   CONTINUE
      DO 110 I=1,NEL
       WRITE (13,95)I,AREA(I),AMIN
       WRITE (5,95)I,AREA(I),AMIN
110   CONTINUE
*
10    FORMAT (/5(A7,4X)/70('-'))
20    FORMAT (//5(I7,4X)/)
30    FORMAT (/3(A7,4X)/40('-'))
40    FORMAT (/I7,4X,2E11.3)
90    FORMAT (//1X,'AREA(',I2,') = ',2F10.2)
95    FORMAT (//1X,I2,2F10.2)
*
      STOP
      END
```

```
*********************************************************
      PROGRAM TRANS3
*********************************************************
C     THIS PROGRAM TRANFORMS THE STRESSES OUTPUT FROM ADINA,
C     EXPRESSED IN THE GLOBAL STRUCTURE COORDINATE SYSTEM, TO
C     THE PRINCIPAL MATERIAL COORDINATE. AND THEN, CALCULATES THE
C     RELIABILTY PER STRESS COMPONENT AND PER ELEMENT AND FINALLY
C     EVALUATES THE TOTAL RELIABILITY. ALL THAT BY CALLING THE
C     SUBROUTINE HEREIN.
C     NEL             : # OF TOTAL ELEMENTS.
C     SX,SY,...,SYZ   : THE STRESS IN GLOBAL COORDINATE SYSTEM.
C     THETA           : THE LAYUP ANGLE PER ELEMENT.
C     S1,S2,... S6    : THE STRESS IN THE MATERIAL PRINCIPAL COORDINATE.
C     R1,R2,...,R6    : THE RELIABILITY PER STRESS COMPONENT.
C     RT1,RT2,...RT6: THE TOTAL RELIABILTY OF STRUCTURE PER COPMPONENT.
C     RE              : THE RELIABILITY PER ELEMENT
C     RT              : THE TOTAL RELIABILITY.
C     ALF             : THE SHAPE FUNCTION PARAMER FOR WEIBULL
C     BEFORE RUNNING THE PROGRAM VERIFY IN THE PROGRAM THE ANGLE THETA
C     INPUT AND THE # OF ELEMENT.AND ALSO VERIFY THE MATERIAL PROEPRTIES
C     GIVEN IN SUBROUTINE BETA.
************************************************************************
      INTEGER NEL
      PARAMETER (NEL=12,PI = 3.1415927 )
      PARAMETER (ROWS=100,COLS=6,COLS1=7)
      INTEGER ITHETA(NEL)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS),C(ROWS,COLS1)
      REAL SX(NEL),SY(NEL),SZ(NEL),SXY(NEL),SXZ(NEL),SYZ(NEL)
      REAL L,M,THETA(NEL),THETAF(NEL),ALF
      CHARACTER*20 FNAME,FNOUT,FNAME1,FNAME2
*
      WRITE (5,*) 'ENTER INPUT STRESS FN  ?'
      READ (5,'(A)') FNAME
      WRITE (5,*) 'INPUT STRESS FN = ',FNAME
      OPEN (UNIT=15,FILE=FNAME,STATUS='OLD')
      WRITE (5,*) 'ENTER INPUT ELEM. ANGLE FN?'
      READ (5,'(A)') FNAME2
      WRITE (5,*) 'INPUT ELEM. ANGLE FN = ',FNAME2
      OPEN (UNIT=16,FILE=FNAME2,STATUS='OLD')
      WRITE (5,*) 'ENTER AREAS OF ELEMENTS FN ?'
      READ (5,'(A)') FNAME1
      OPEN (UNIT=17,FILE=FNAME1,STATUS='OLD')
      WRITE (5,*) ' ENTER OUTPUT FN ?'
      READ (5,'(A)') FNOUT
      OPEN (UNIT=13,FILE=FNOUT,STATUS='NEW')
      WRITE (13,*) 'INPUT STRESS FN = ',FNAME
      WRITE (13,*) 'INPUT ELEM. ANGLE FN = ',FNAME2
      WRITE (13,*) 'INPUT  AREAS OF ELEMENTS FN =',FNAME1
      WRITE (13,*) ' OUTPUT FN =',FNOUT
*
*INPUT OF ANGLE (THETA) FOR EA. ELEMENT ;
*-------------------------------------
      DO 20 I=1,NEL
      READ (16,*) N,I2,I3,I4,I5,I6,ITHETA(I),I8,A9,A10,I11,
     &            I12,I13,I14,I15,I16,I17,I18,I19
       IF (ITHETA(I).EQ.1) THETA(I) = 90.0
       IF (ITHETA(I).EQ.3) THETA(I) = 75.0
       WRITE (5,25) N,THETA(I)
        THETAF(I) = THETA(I)* PI/180.0
 20   CONTINUE
```

```
*
      WRITE (13,*) 'OUTPUT :',FNOUT
*
*TRANSFORMATION OF STRESSES TO PRINCIPAL AXES STRESS ;
*-----------------------------------------------------
      WRITE (13,11) 'NEL','SX','SY', 'SZ','SXY','SXZ','SYZ','ANGLE'
      DO 55 I=1,NEL
      READ (15,*) IEL,NOD,SX(I),SY(I),SZ(I),SXY(I),SXZ(I),SYZ(I)
      THETA(I) = THETAF(I)*180.0 / PI
      WRITE (13,61) IEL,SX(I),SY(I),SZ(I),SXY(I),SXZ(I),SYZ(I),
     &                THETA(I)

*
      L=COS(THETAF(I))
      M=SIN(THETAF(I))
        A(I,1)= SX(I)*(L**2) + SY(I)*(M**2) + 2*SXY(I)*L*M
        A(I,2)= SX(I)*(M**2) + SY(I)*(L**2) - 2*SXY(I)*L*M
        A(I,3)= SZ(I)
        A(I,6)= -SX(I)*L*M + SY(I)*M*L + SXY(I)*(L**2 - M**2)
        A(I,5)= SYZ(I)*M + SXZ(I)*L
        A(I,4)= SYZ(I)*L - SXZ(I)*M
55    CONTINUE
      WRITE (13,10) 'NEL','S1','S2','S3','S6','S5','S4'
      DO 80 I=1,NEL
      WRITE (13,60) I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
80    CONTINUE
*
*SUBROUTINES FOR CALCULATING THE RELIABILITY ;
*----------------------------------------------
      CALL BETA(A,B,NEL)
      WRITE (5,*) 'INPUT ALFA'
      READ  (5,*) ALF
      WRITE (13,*) 'ALFA :',ALF
      CALL ALFA(A,B,NEL,ALF)
      CALL RELI(A,B,NEL)
      CALL ELRE(B,NEL)
*
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
11    FORMAT (//,1X,A10,7(A7,4X) / 1X,80('-'))
15    FORMAT (1X,'THETA(',I2,')= ')
25    FORMAT (1X,'THETA(',I2,')= ',F6.1)
60    FORMAT (/,4X,I6,6E11.3)
61    FORMAT (/,4X,I6,6E11.3,3X,F6.1)
*
      STOP
      END
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
******************************
      SUBROUTINE BETA(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL X(COLS),X1C,X2C,X3C
*
* PLY STRESS - STRENGTH,RATIO CALCULATION :
*-----------------------------------------
      WRITE (13,10) 'NEL','SR1','SR2','SR3','SR6','SR5','SR4'
      DO 90 I=1,NEL
C STRENGTH PROPERTIES FOR GRAPHITE EPOXY,
C.......................................
```

```
         X(1)  = 15.0E4
         X(2)  = 0.4E4
         X(3)  = X(2)
         X(6)  = 0.68E4
         X(4)  = X(6)
         X(5)  = X(6)
         X1C = -15.0E4
         X2C = -2.46E4
         X3C = X2C
         IF (A(I,1).LT.0) X(1) = X1C
         IF (A(I,2).LT.0) X(2) = X2C
         IF (A(I,3).LT.0) X(3) = X3C
      DO 80 J=1,COLS
         B(I,J) = ABS(A(I,J) / X(J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END

*********************************
      SUBROUTINE ALFA(A,B,NEL,ALF)
*********************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL AREA(100),AMIN
*
* PLY STRESS - STRENGTH,RATIO RISED BY ALFA CALCULATION :
*-------------------------------------------------------
      WRITE (13,10) 'NEL','V1','V2','V3','V6','V5','V4'
      DO 90 I=1,NEL
      READ (17,*) IIEL,AREA(I),AMIN
          AMIN=400.
      WRITE (5,95) IIEL,AREA(I),AMIN
      WRITE (3,95) IIEL,AREA(I),AMIN
      DO 80 J=1,COLS
*         A(I,J) = B(I,J)**ALF
         A(I,J) = (B(I,J)**ALF)*AREA(I)/AMIN
80    CONTINUE
      WRITE (13,60)I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
95    FORMAT (//1X,'AREA(',I2,') = ',2F10.2)
      RETURN
      END

*****************************
      SUBROUTINE RELI(A,B,NEL)
*****************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
*
* PLY STERSS TENSOR RELIABILITY CALCULATION (WEIBULL) :
*-----------------------------------------------------
      WRITE (13,10) 'NEL','R1','R2','R3','R6','R5','R4'
      DO 90 I=1,NEL
      DO 80 J=1,COLS
```

```
          B(I,J) = EXP(-A(I,J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END
*****************************
      SUBROUTINE ELRE(B,NEL)
*****************************
      PARAMETER (ROWS=100,COLS=6,COLS1=7)
      REAL*8 B(ROWS,COLS),C(ROWS,COLS1),RT
*
*ELEMENTS RELIABILITY CALCUL., AS WELL AS "FIBER" (R1) AND "MATRIX"
*RELIABILITY CALCUL.& TOTAL STRUCTURE RELIABILITY CALCUL.
*-------------------------------------------------------------
      WRITE (13,10)'NEL','R1','R2','R3','R6','R5','R4','RE'
      RT =1.0
      C(NEL+1,1)=1.0
      DO 90 I=1,NEL
      C(I,COLS1) = 1.0
      DO 80 J=1,COLS
           C(I,J)=B(I,J)
           C(I,COLS1) = C(I,COLS1) * C(I,J)
           C(NEL+1,J) = C(NEL+1,J) * C(I,J)
80    CONTINUE
      RT = RT * C(I,COLS1)
      WRITE (5,60) I,C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6),C(I,7)
      WRITE (13,60) I,C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6),C(I,7)
90    CONTINUE
      WRITE (13,10) 'TOTAL REL.:','RT1','RT2','RT3','RT6','RT5',
     &               'RT4','RT'
      WRITE (13,65) C(NEL+1,1),C(NEL+1,2),C(NEL+1,3),C(NEL+1,4),
     &               C(NEL+1,5),C(NEL+1,6),RT
      WRITE (5,70) RT
      WRITE (13,70) RT
10    FORMAT (//,1X,A10,7(A7,4X) / 1X,95('-'))
60    FORMAT (/,4X,I6,7E11.3)
65    FORMAT (/,11X,7E11.3)
70    FORMAT (//,1X,'TOTAL STRUCTURE RELIABILITY = ',E11.3 /1X,40('='))
      RETURN
      END
```

```
INPUT STRESS FN = THV3D.STR
INPUT ELEM. ANGLE FN = THV3D.EL
INPUT  AREAS OF ELEMENTS FN =THV3D.AREA
 OUTPUT FN =THV3D.REL
OUTPUT :THV3D.REL

       NEL      SX          SY          SZ          SXY         SXZ         SYZ      ANGLE
-------------------------------------------------------------------------------------

         1 -0.279E+03  0.391E+05 -0.286E+01 -0.235E+04  0.254E+01 -0.983E+01      90.0

         2  0.277E+03  0.209E+05 -0.268E+01  0.235E+04  0.254E+01 -0.976E+01      75.0

         3  0.277E+03  0.209E+05 -0.268E+01  0.235E+04 -0.254E+01  0.976E+01      75.0

         4 -0.279E+03  0.391E+05 -0.286E+01 -0.235E+04 -0.254E+01  0.983E+01      90.0

         5 -0.316E+03  0.390E+05 -0.881E+02 -0.235E+04  0.742E-01 -0.566E+00      90.0

         6  0.243E+03  0.209E+05 -0.754E+02  0.235E+04  0.742E-01 -0.332E+00      75.0

         7  0.243E+03  0.209E+05 -0.754E+02  0.235E+04 -0.742E-01  0.332E+00      75.0

         8 -0.316E+03  0.390E+05 -0.881E+02 -0.235E+04 -0.742E-01  0.566E+00      90.0

         1 -0.287E+03  0.391E+05 -0.169E+02 -0.235E+04  0.494E+00 -0.216E+01      90.0

         2  0.270E+03  0.209E+05 -0.146E+02  0.235E+04  0.494E+00 -0.196E+01      75.0

         3  0.270E+03  0.209E+05 -0.146E+02  0.235E+04 -0.494E+00  0.196E+01      75.0

         4 -0.287E+03  0.391E+05 -0.169E+02 -0.235E+04 -0.494E+00  0.216E+01      90.0

       NEL      S1          S2          S3          S6          S5          S4
-------------------------------------------------------------------------------------

         1  0.391E+05 -0.279E+03 -0.286E+01  0.235E+04 -0.983E+01 -0.254E+01

         2  0.207E+05  0.484E+03 -0.268E+01  0.313E+04 -0.877E+01 -0.498E+01

         3  0.207E+05  0.484E+03 -0.268E+01  0.313E+04  0.877E+01  0.498E+01

         4  0.391E+05 -0.279E+03 -0.286E+01  0.235E+04  0.983E+01  0.254E+01

         5  0.390E+05 -0.316E+03 -0.881E+02  0.235E+04 -0.566E+00 -0.742E-01

         6  0.207E+05  0.451E+03 -0.754E+02  0.313E+04 -0.301E+00 -0.158E+00

         7  0.207E+05  0.451E+03 -0.754E+02  0.313E+04  0.301E+00  0.158E+00

         8  0.390E+05 -0.316E+03 -0.881E+02  0.235E+04  0.566E+00  0.742E-01

         9  0.391E+05 -0.287E+03 -0.169E+02  0.235E+04 -0.216E+01 -0.494E+00

        10  0.207E+05  0.477E+03 -0.146E+02  0.313E+04 -0.177E+01 -0.985E+00

        11  0.207E+05  0.477E+03 -0.146E+02  0.313E+04  0.177E+01  0.985E+00
```

```
     12  0.391E+05 -0.287E+03 -0.169E+02  0.235E+04  0.216E+01  0.494E+00

ALFA :    5.000000

     NEL     R1         R2         R3         R6         R5         R4         RE
-----------------------------------------------------------------------------------------

       1  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.993E+00  0.991E+00

       2  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.970E+00  0.970E+00

       3  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.970E+00  0.970E+00

       4  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.993E+00  0.991E+00

       5  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.993E+00  0.991E+00

       6  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.970E+00  0.969E+00

       7  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.970E+00  0.969E+00

       8  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.993E+00  0.991E+00

       9  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00

      10  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.980E+00  0.980E+00

      11  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.980E+00  0.980E+00

      12  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00

TOTAL REL.    RT1        RT2        RT3        RT6        RT5        RT4        RT
-----------------------------------------------------------------------------------------

           0.990E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.807E+00

TOTAL STRUCTURE RELIABILITY =   0.807E+00
========================================
```

APPENDIX D

APPLICATIONS

We are again considering the simply supported anisotropic square plate with uniform tensile load, described in the former appendices.

Here, the meshing used is modeling a conventional repair of a damaged structure. We are thereby calculating the reliability for different configurations.

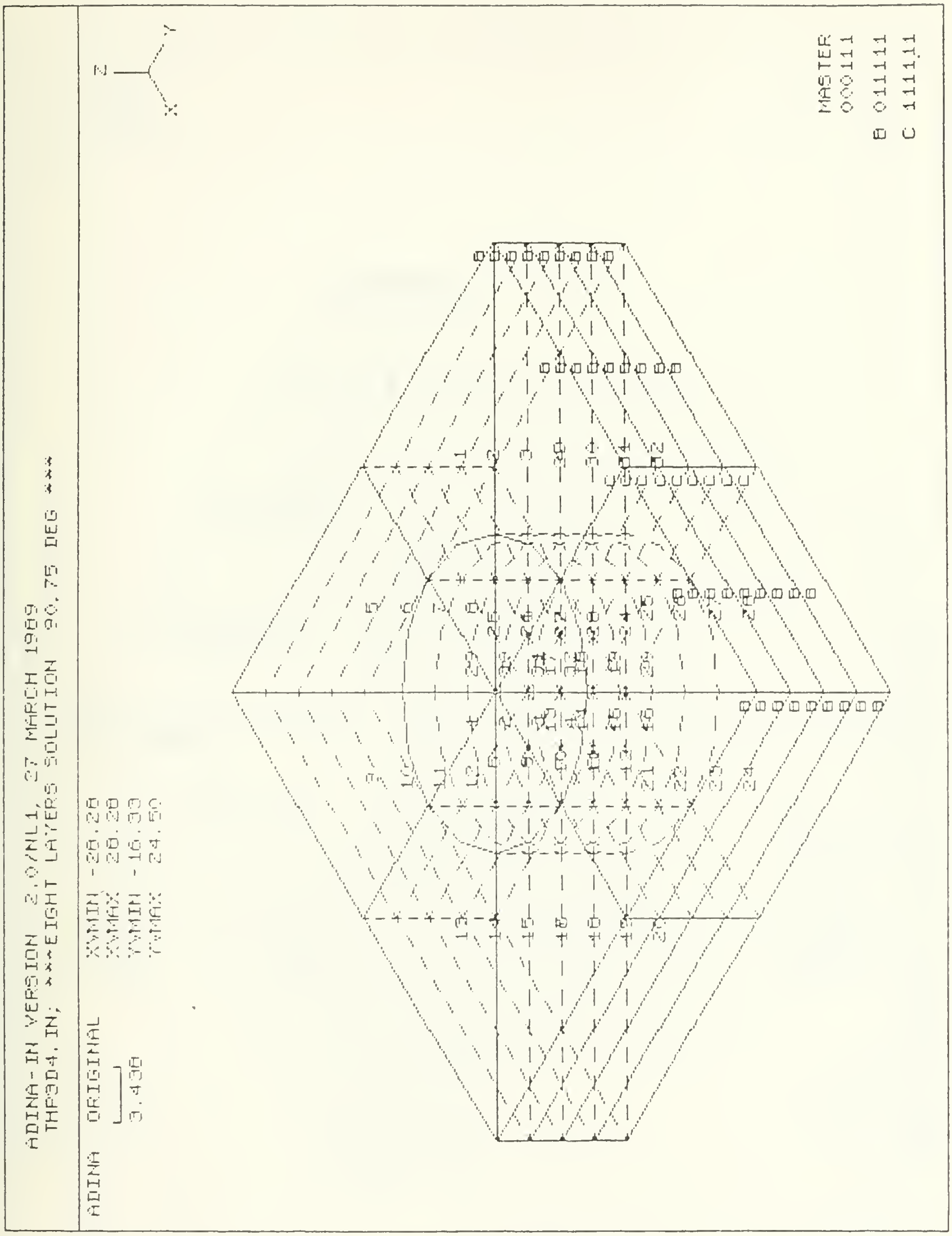
Using the THP3D4 program, the verification problem (THV3D) is solved with different mesh sizes (i.e., different element sizes). Comparing the results for the total reliability, we may conclude that the results are in good agreement with each other (R_T(THV3D) = 0.807, R_T(THP3D4) = 0.824).

The THM3D4 program analyzes the parent structure with a hole. The resulting total reliability is 0 (R_T = 0.0). In other words, the structure will probably fail due to the given applied load.

The THM3D4 program simulates a repair configuration using a weaker material (E-glass/epoxy instead of graphite/epoxy used for the original parent structure). The reliability decreases in comparison with the original undamaged structure, R_T = 0.1.

To improve the total reliability, in the THA3D4 program we simulate a repair configuration by using a different lay-up orientation ($[90_4]$) for the patch and, as expected, the repair causes the total structure to be more reliable, R_T = 0.87.

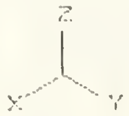
In summary, from all the individual results for the computed reliabilities listed in the programs below, we can interpret the critical element (see RE in the results) or the critical stress component (see RT1, RT2, etc.), which may represent the fiber or the matrix of the composite material.

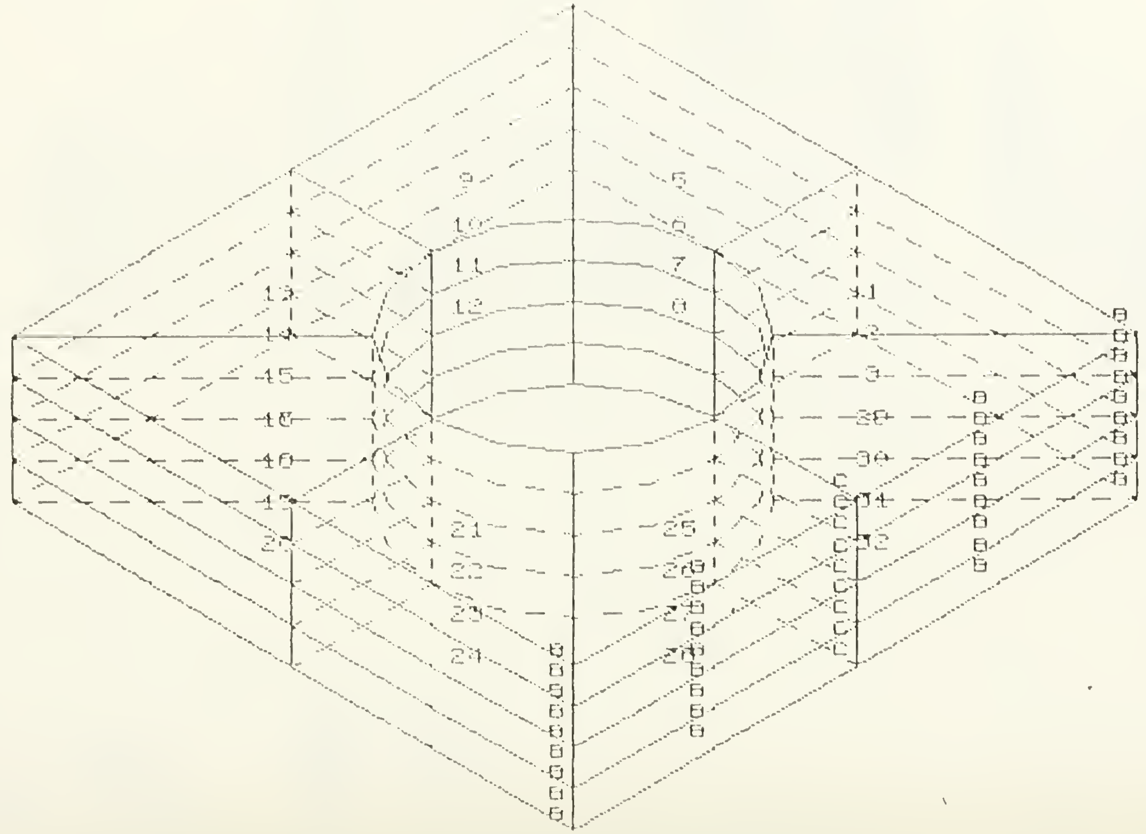

ADINA-IN VERSION 2.0/NL1, 27 MARCH 1989
THP3D4.IN; ***EIGHT LAYERS SOLUTION 90,75 DEG ***
ADINA ORIGINAL
3.438
XVMIN -28.28
XVMAX 28.28
YVMIN -16.33
YVMAX 24.50
Z
X
Y
MASTER
000111
B 011111
C 111111

ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THP3D4.IN; ***EIGHT LAYERS SOLUTION 90,75 DEG ***

ADINA ORIGINAL
3.430

XVMIN -20.20
XVMAX 20.20
YVMIN -16.33
YVMAX 24.50

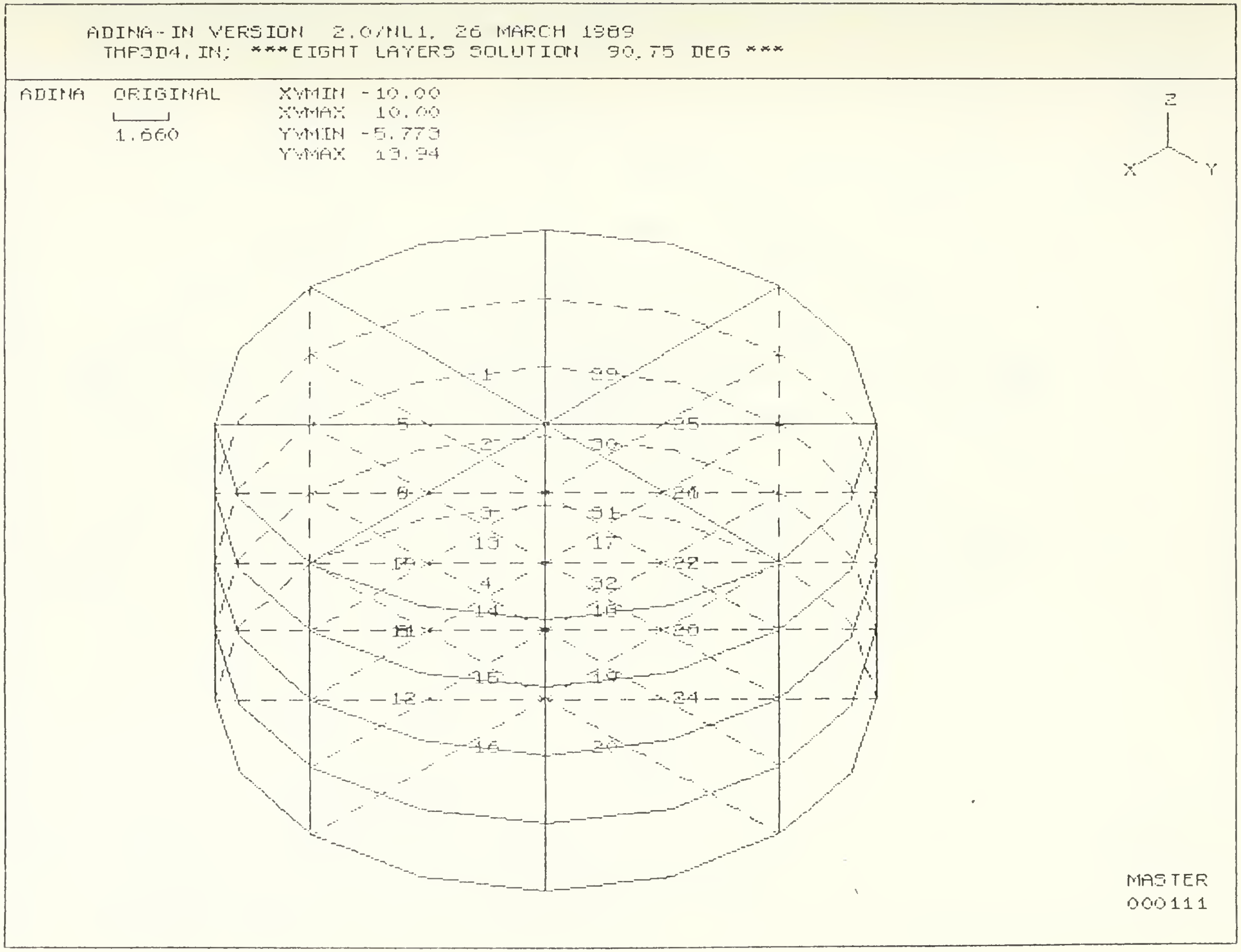


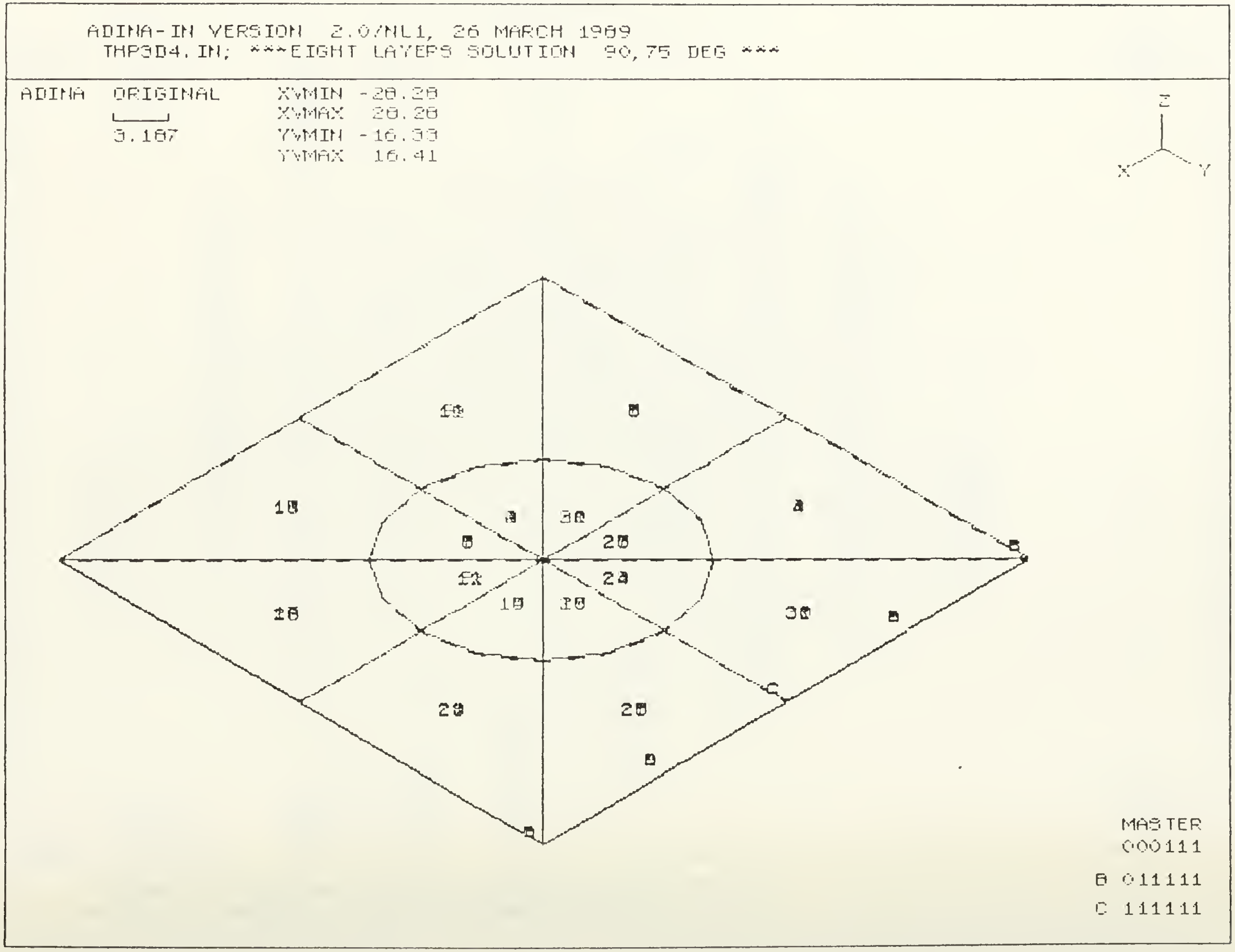


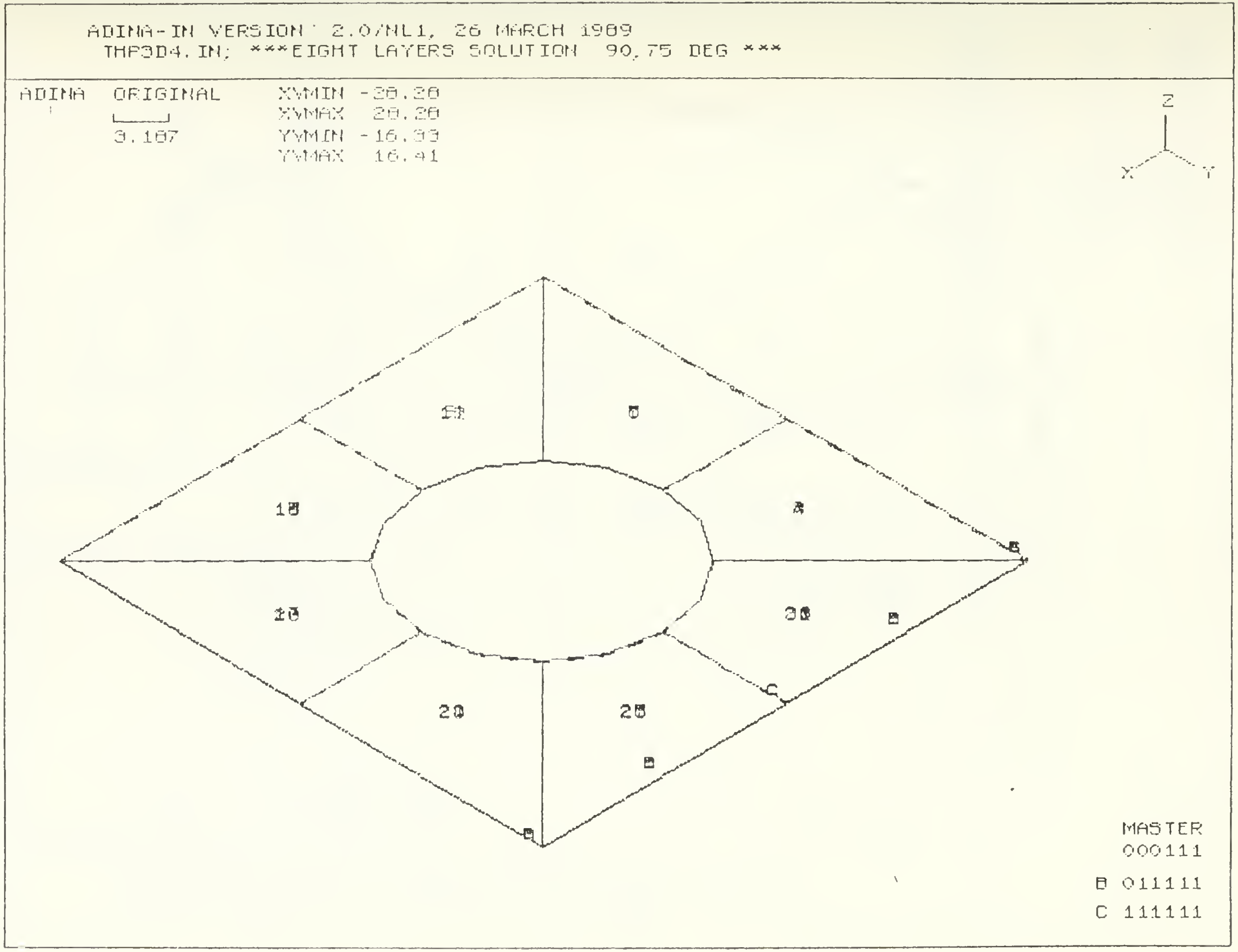
MASTER
000111

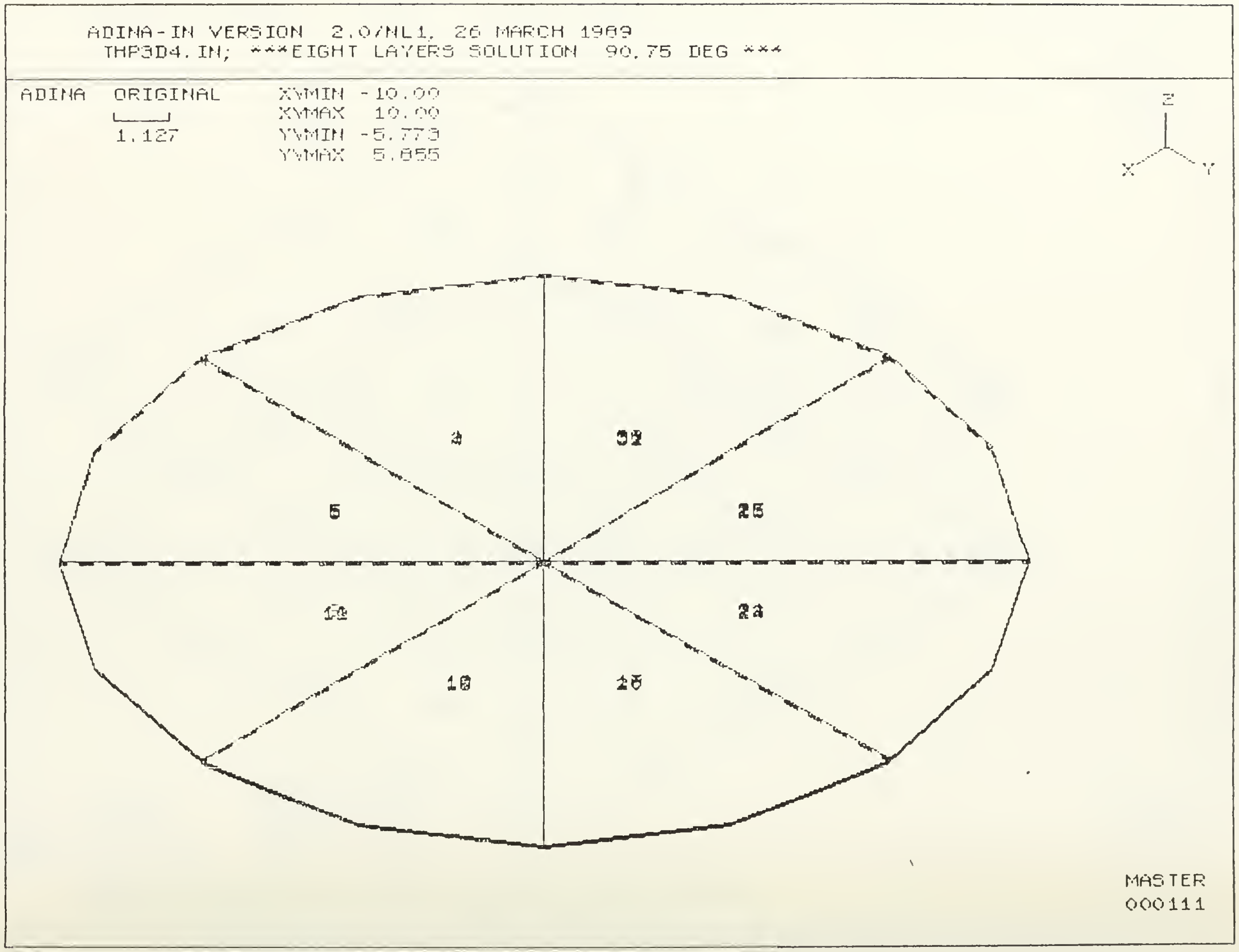
B 011111

C 111111


ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THP3D4.IN; ***EIGHT LAYERS SOLUTION 90.75 DEG ***
ADINA ORIGINAL
1.660
XVMIN -10.00
XVMAX 10.00
YVMIN -5.773
YVMAX 13.94
Z
X
Y
1
29
5
25
2
30
6
26
3
31
13
17
4
32
14
18
15
19
12
24
16
20
MASTER
000111


ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THP3D4.IN; ***EIGHT LAYERS SOLUTION 90,75 DEG ***
ADINA ORIGINAL
3.187
XVMIN -20.28
XVMAX 20.28
YVMIN -16.33
YVMAX 16.41
Z
X
Y
MASTER
000111
B 011111
C 111111
C


ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THP3D4.IN; ***EIGHT LAYERS SOLUTION 90,75 DEG ***
ADINA ORIGINAL
3.187
XVMIN -28.28
XVMAX 28.28
YVMIN -16.33
YVMAX 16.41
Z
X
Y
MASTER
000111
B 011111
C 111111
B
C


ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THP3D4.IN; ***EIGHT LAYERS SOLUTION 90.75 DEG ***
ADINA ORIGINAL
1.127
XVMIN -10.00
XVMAX 10.00
YVMIN -5.773
YVMAX 5.855
Z
X
Y
4
32
5
25
12
24
18
26
MASTER
000111

```
*       A D I N A - I N    I N P U T    F I L E
*
* THP3D4.IN EIGHT SYMMETRIC LAYER USING 3-D.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THP3D4.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE     X      Y     Z
                         1     -20.   -20.  0.1
                         2       0.   -20.  0.1
                         3      20.   -20.  0.1
                         4     -20.     0.  0.1
                         5       0.     0.  0.1
                         6      20.     0.  0.1
                         7     -20.    20.  0.1
                         8       0.    20.  0.1
                         9      20.    20.  0.1
                        21     -20.   -20.  0.
                        22       0.   -20.  0.
                        23      20.   -20.  0.
                        24     -20.     0.  0.
                        25       0.     0.  0.
                        26      20.     0.  0.
                        27     -20.    20.  0.
                        28       0.    20.  0.
                        29      20.    20.  0.
                       101       5.     0.  0.
                       102       0.    10.  0.
                       103       5.    10.  0.
                       104      15.     2.68 0.
                       105       7.68  10.    0.
                       106      15.    10.    0.
                       107      15.   -10.    0.
*================================================
*NOTE THE MAXES MEAN : 1=90DEG 2=15 3=75 4=45 5=-45
*================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                      GAB=7.17E05 7.17E05 7.17E05
*
SYSTEM 1 CYLINDRIC X=0 Y=0 Z=0 PHI=0 THETA=-90. XSI=90.
COORDINATES / ENTRIES NODES R THETA      XL
                       10    10.  0.       0.1
                       11    10.  45.      0.1
                       12    10.  90.      0.1
                       13    10.  135.     0.1
                       14    10.  180.     0.1
                       15    10.  225.     0.1
                       16    10.  270.     0.1
                       17    10.  315.     0.1
```

```
                     18    10.  360.   0.1
                     30    10.  0.     0.
                     31    10.  45.    0.
                     32    10.  90.    0.
                     33    10.  135.   0.
                     34    10.  180.   0.
                     35    10.  225.   0.
                     36    10.  270.   0.
                     37    10.  315.   0.
                     38    10.  360.   0.
*
LINE CYLINDRIC 11 10 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 12 11 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 13 12 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 14 13 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 15 14 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 16 15 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 17 16 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 18 17 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 31 30 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 32 31 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 33 32 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 34 33 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 35 34 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 36 35 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 37 36 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 38 37 EL=1 MIDNODES=1 NC=A
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 7 4 18 17 27 24 38 37 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 4 1 11 10 24 21 31 30 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 1 2 12 11 21 22 32 31 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 2 3 13 12 22 23 33 32 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 3 6 14 13 23 26 34 33 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 6 9 15 14 26 29 35 34 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 8 16 15 29 28 36 35 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 8 7 17 16 28 27 37 36 EL1=1 EL2=1 EL3=4 NODES=27
GSURFACE 7 8 28 27   EL1=1 EL2=4 NO=9
GSURFACE 8 9 29 28   EL1=1 EL2=4 NO=9
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1     1      1
  STEP 4 TO
                29    1      1
                2     1      3
  STEP 4 TO
                30    1      3
                3     1      3
  STEP 4 TO
                31    1      3
                4     1      1
  STEP 4 TO
                32    1      1
*
```

```
LOADS ELEMENT
             9  2  -3.0E04
        TO
             16  2  -3.0E04

*
FIXB 123 LINES / 8 28
FIXB 23 SURFACES /  7 8 28 27 / 8 9 29 28
*
*
EGROUP 2 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 11 12 5 5 31 32 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 12 13 5 5 32 33 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 13 14 5 5 33 34 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 14 15 5 5 34 35 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 15 16 5 5 35 36 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 16 17 5 5 36 37 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 17 18 5 5 37 38 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 10 11 5 5 30 31 25 25 EL1=1 EL2=1 EL3=4 NODES=27
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1     1      1
  STEP 4 TO
                29    1      1
                2     1      3
  STEP 4 TO
                30    1      3
                3     1      3
  STEP 4 TO
                31    1      3
                4     1      1
  STEP 4 TO
                32    1      1
*
*
EGZONE NAME=PARENT / 1 / 2
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=PARENT NODES=0 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
*MESH ZONE=PATCH NODES=0 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

```
**********************************************************
      PROGRAM TRANS3
**********************************************************
C     THIS PROGRAM TRANFORMS THE STRESSES OUTPUT FROM ADINA,
C     EXPRESSED IN THE GLOBAL STRUCTURE COORDINATE SYSTEM, TO
C     THE PRINCIPAL MATERIAL COORDINATE. AND THEN, CALCULATES THE
C     RELIABILTY PER STRESS COMPONENT AND PER ELEMENT AND FINALLY
C     EVALUATES THE TOTAL RELIABILITY. ALL THAT BY CALLING THE
C     SUBROUTINE HEREIN.
C     NEL           : # OF TOTAL ELEMENTS.
C     SX,SY,...,SYZ : THE STRESS IN GLOBAL COORDINATE SYSTEM.
C     THETA         : THE LAYUP ANGLE PER ELEMENT.
C     S1,S2,... S6  : THE STRESS IN THE MATERIAL PRINCIPAL COORDINATE.
C     R1,R2,...,R6  : THE RELIABILITY PER STRESS COMPONENT.
C     RT1,RT2,...RT6: THE TOTAL RELIABILTY OF STRUCTURE PER COPMPONENT.
C     RE            : THE RELIABILITY PER ELEMENT
C     RT            : THE TOTAL RELIABILITY.
C     ALF           : THE SHAPE FUNCTION PARAMER FOR WEIBULL
C     BEFORE RUNNING THE PROGRAM VERIFY IN THE PROGRAM THE ANGLE THETA
C     INPUT AND THE # OF ELEMENT.AND ALSO VERIFY THE MATERIAL PROEPRTIES
C     GIVEN IN SUBROUTINE BETA.
*************************************************************************
      INTEGER NEL
      PARAMETER (NEL=64,PI = 3.1415927 )
      PARAMETER (ROWS=100,COLS=6,COLS1=7)
      INTEGER ITHETA(NEL)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS),C(ROWS,COLS1)
      REAL SX(NEL),SY(NEL),SZ(NEL),SXY(NEL),SXZ(NEL),SYZ(NEL)
      REAL L,M,THETA(NEL),THETAF(NEL),ALF
      CHARACTER*20 FNAME,FNOUT,FNAME1,FNAME2
*
      WRITE (5,*) 'ENTER INPUT STRESS FN  ?'
      READ (5,'(A)') FNAME
      WRITE (5,*) 'INPUT STRESS FN = ',FNAME
      OPEN (UNIT=15,FILE=FNAME,STATUS='OLD')
      WRITE (5,*) 'ENTER INPUT ELEM. ANGLE FN?'
      READ (5,'(A)') FNAME2
      WRITE (5,*) 'INPUT ELEM. ANGLE FN = ',FNAME2
      OPEN (UNIT=16,FILE=FNAME2,STATUS='OLD')
      WRITE (5,*) 'ENTER AREAS OF ELEMENTS FN ?'
      READ (5,'(A)') FNAME1
      OPEN (UNIT=17,FILE=FNAME1,STATUS='OLD')
      WRITE (5,*) ' ENTER OUTPUT FN ?'
      READ (5,'(A)') FNOUT
      OPEN (UNIT=13,FILE=FNOUT,STATUS='NEW')
      WRITE (13,*) 'INPUT STRESS FN = ',FNAME
      WRITE (13,*) 'INPUT ELEM. ANGLE FN = ',FNAME2
      WRITE (13,*) 'INPUT  AREAS OF ELEMENTS FN =',FNAME1
      WRITE (13,*) ' OUTPUT FN =',FNOUT
*
*INPUT OF ANGLE (THETA) FOR EA. ELEMENT ;
*----------------------------------------
      DO 20 I=1,NEL
      READ (16,*) N,I2,I3,I4,I5,I6,ITHETA(I),I8,A9,A10,I11,
     &            I12,I13,I14,I15,I16,I17,I18,I19
       IF (ITHETA(I).EQ.1) THETA(I) = 90.0
       IF (ITHETA(I).EQ.3) THETA(I) = 75.0
       WRITE (5,25) N,THETA(I)
        THETAF(I) = THETA(I)* PI/180.0
20    CONTINUE
```

```
*
      WRITE (13,*) 'OUTPUT :',FNOUT
*
*TRANSFORMATION OF STRESSES TO PRINCIPAL AXES STRESS ;
*--------------------------------------------------------
      WRITE (13,11) 'NEL','SX','SY', 'SZ','SXY','SXZ','SYZ','ANGLE'
      DO 55 I=1,NEL
      READ (15,*) IEL,NOD,SX(I),SY(I),SZ(I),SXY(I),SXZ(I),SYZ(I)
      THETA(I) = THETAF(I)*180.0 / PI
      WRITE (13,61) IEL,SX(I),SY(I),SZ(I),SXY(I),SXZ(I),SYZ(I),
     &                  THETA(I)

*
      L=COS(THETAF(I))
      M=SIN(THETAF(I))
        A(I,1)= SX(I)*(L**2) + SY(I)*(M**2) + 2*SXY(I)*L*M
        A(I,2)= SX(I)*(M**2) + SY(I)*(L**2) - 2*SXY(I)*L*M
        A(I,3)= SZ(I)
        A(I,6)= -SX(I)*L*M + SY(I)*M*L + SXY(I)*(L**2 - M**2)
        A(I,5)= SYZ(I)*M + SXZ(I)*L
        A(I,4)= SYZ(I)*L - SXZ(I)*M
55    CONTINUE
      WRITE (13,10) 'NEL','S1','S2','S3','S6','S5','S4'
      DO 80 I=1,NEL
      WRITE (13,60) I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
80    CONTINUE
*
*SUBROUTINES FOR CALCULATING THE RELIABILITY ;
*-------------------------------------------------
      CALL BETA(A,B,NEL)
      WRITE (5,*) 'INPUT ALFA'
      READ  (5,*) ALF
      WRITE (13,*) 'ALFA :',ALF
      CALL ALFA(A,B,NEL,ALF)
      CALL RELI(A,B,NEL)
      CALL ELRE(B,NEL)
*
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
11    FORMAT (//,1X,A10,7(A7,4X) / 1X,80('-'))
15    FORMAT (1X,'THETA(',I2,')= ')
25    FORMAT (1X,'THETA(',I2,')= ',F6.1)
60    FORMAT (/,4X,I6,6E11.3)
61    FORMAT (/,4X,I6,6E11.3,3X,F6.1)
*
      STOP
      END
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
******************************
      SUBROUTINE BETA(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL X(COLS),X1C,X2C,X3C
*
* PLY STRESS - STRENGTH,RATIO CALCULATION :
*------------------------------------------
      WRITE (13,10) 'NEL','SR1','SR2','SR3','SR6','SR5','SR4'
      DO 90 I=1,NEL
C STRENGTH PROPERTIES FOR GRAPHITE EPOXY,
C.......................................
```

```
         X(1)  = 15.0E4
         X(2)  = 0.4E4
         X(3)  = X(2)
         X(6)  = 0.68E4
         X(4)  = X(6)
         X(5)  = X(6)
         X1C = -15.0E4
         X2C = -2.46E4
         X3C = X2C
         IF (A(I,1).LT.0) X(1) = X1C
         IF (A(I,2).LT.0) X(2) = X2C
         IF (A(I,3).LT.0) X(3) = X3C
      DO 80 J=1,COLS
         B(I,J) = ABS(A(I,J) / X(J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END

*********************************
      SUBROUTINE ALFA(A,B,NEL,ALF)
*********************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL AREA(100),AMIN
*
* PLY STRESS - STRENGTH,RATIO RISED BY ALFA CALCULATION :
*-------------------------------------------------------
      WRITE (13,10) 'NEL','V1','V2','V3','V6','V5','V4'
      DO 90 I=1,NEL
      READ (17,*) IIEL,AREA(I),AMIN
          AMIN=400.
      WRITE (5,95) IIEL,AREA(I),AMIN
      WRITE (3,95) IIEL,AREA(I),AMIN
      DO 80 J=1,COLS
*         A(I,J) = B(I,J)**ALF
         A(I,J) = (B(I,J)**ALF)*AREA(I)/AMIN
80    CONTINUE
      WRITE (13,60)I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
95    FORMAT (//1X,'AREA(',I2,') = ',2F10.2)
      RETURN
      END

******************************
      SUBROUTINE RELI(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
*
* PLY STERSS TENSOR RELIABILITY CALCULATION (WEIBULL) :
*-----------------------------------------------------
      WRITE (13,10) 'NEL','R1','R2','R3','R6','R5','R4'
      DO 90 I=1,NEL
      DO 80 J=1,COLS
```

```
            B(I,J) = EXP(-A(I,J))
80      CONTINUE
        WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90      CONTINUE
10      FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60      FORMAT (/,4X,I6,6E11.3)
        RETURN
        END
******************************
        SUBROUTINE ELRE(B,NEL)
******************************
        PARAMETER (ROWS=100,COLS=6,COLS1=7)
        REAL*8 B(ROWS,COLS),C(ROWS,COLS1),RT
*
*ELEMENTS RELIABILITY CALCUL., AS WELL AS "FIBER" (R1) AND "MATRIX"
*RELIABILITY CALCUL.& TOTAL STRUCTURE RELIABILITY CALCUL.
*------------------------------------------------------------
        WRITE (13,10)'NEL','R1','R2','R3','R6','R5','R4','RE'
        RT =1.0
        C(NEL+1,1)=1.0
        DO 90 I=1,NEL
        C(I,COLS1) = 1.0
        DO 80 J=1,COLS
             C(I,J)=B(I,J)
             C(I,COLS1) = C(I,COLS1) * C(I,J)
             C(NEL+1,J) = C(NEL+1,J) * C(I,J)
80      CONTINUE
        RT = RT * C(I,COLS1)
        WRITE (5,60) I,C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6),C(I,7)
        WRITE (13,60) I,C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6),C(I,7)
90      CONTINUE
        WRITE (13,10) 'TOTAL REL.:','RT1','RT2','RT3','RT6','RT5',
       &              'RT4','RT'
        WRITE (13,65) C(NEL+1,1),C(NEL+1,2),C(NEL+1,3),C(NEL+1,4),
       &               C(NEL+1,5),C(NEL+1,6),RT
        WRITE (5,70) RT
        WRITE (13,70) RT
10      FORMAT (//,1X,A10,7(A7,4X) / 1X,95('-'))
60      FORMAT (/,4X,I6,7E11.3)
65      FORMAT (/,11X,7E11.3)
70      FORMAT (//,1X,'TOTAL STRUCTURE RELIABILITY = ',E11.3 /1X,40('='))
        RETURN
        END
```

```
INPUT STRESS FN = THP3D4.STR
INPUT ELEM. ANGLE FN = THP3D4.EL
INPUT  AREAS OF ELEMENTS FN =THP3D4.AREA
OUTPUT :THP3D4.REL

       NEL     SX          SY          SZ          SXY         SXZ         SYZ       ANGLE
-----------------------------------------------------------------------------------------

         1 -0.277E+03  0.391E+05  0.187E+02 -0.235E+04  0.909E+00  0.622E+01       90.0

         2  0.279E+03  0.209E+05  0.160E+02  0.236E+04  0.849E+00  0.604E+01       75.0

         3  0.279E+03  0.209E+05  0.160E+02  0.236E+04 -0.849E+00 -0.604E+01       75.0

         4 -0.277E+03  0.391E+05  0.187E+02 -0.235E+04 -0.909E+00 -0.622E+01       90.0

         5 -0.278E+03  0.391E+05  0.248E+01 -0.235E+04  0.399E+00  0.675E+01       90.0

         6  0.279E+03  0.209E+05  0.217E+01  0.235E+04  0.361E+00  0.683E+01       75.0

         7  0.279E+03  0.209E+05  0.217E+01  0.235E+04 -0.361E+00 -0.683E+01       75.0

         8 -0.278E+03  0.391E+05  0.248E+01 -0.235E+04 -0.399E+00 -0.675E+01       90.0

         9 -0.278E+03  0.391E+05  0.653E-01 -0.235E+04  0.552E+01 -0.216E+02       90.0

        10  0.278E+03  0.209E+05 -0.746E+00  0.235E+04  0.553E+01 -0.216E+02       75.0

        11  0.278E+03  0.209E+05 -0.746E+00  0.235E+04 -0.553E+01  0.216E+02       75.0

        12 -0.278E+03  0.391E+05  0.653E-01 -0.235E+04 -0.552E+01  0.216E+02       90.0

        13 -0.278E+03  0.391E+05  0.113E+00 -0.235E+04  0.559E+01 -0.210E+02       90.0

        14  0.278E+03  0.209E+05 -0.692E+00  0.235E+04  0.559E+01 -0.210E+02       75.0

        15  0.278E+03  0.209E+05 -0.692E+00  0.235E+04 -0.559E+01  0.210E+02       75.0

        16 -0.278E+03  0.391E+05  0.113E+00 -0.235E+04 -0.559E+01  0.210E+02       90.0

        17 -0.278E+03  0.391E+05  0.250E+01 -0.235E+04 -0.992E+00 -0.434E+01       90.0

        18  0.279E+03  0.209E+05  0.218E+01  0.235E+04 -0.967E+00 -0.438E+01       75.0

        19  0.279E+03  0.209E+05  0.218E+01  0.235E+04  0.967E+00  0.438E+01       75.0

        20 -0.278E+03  0.391E+05  0.250E+01 -0.235E+04  0.992E+00  0.434E+01       90.0

        21 -0.278E+03  0.391E+05  0.190E+02 -0.236E+04 -0.608E+00 -0.566E+01       90.0

        22  0.277E+03  0.209E+05  0.163E+02  0.235E+04 -0.550E+00 -0.573E+01       75.0

        23  0.277E+03  0.209E+05  0.163E+02  0.235E+04  0.550E+00  0.573E+01       75.0

        24 -0.278E+03  0.391E+05  0.190E+02 -0.236E+04  0.608E+00  0.566E+01       90.0

        25 -0.318E+03  0.390E+05 -0.115E+03 -0.235E+04 -0.598E+01 -0.109E+01       90.0

        26  0.243E+03  0.209E+05 -0.982E+02  0.235E+04 -0.607E+01 -0.414E+00       75.0
```

```
27  0.243E+03  0.209E+05 -0.982E+02  0.235E+04  0.607E+01  0.414E+00     75.0
28 -0.318E+03  0.390E+05 -0.115E+03 -0.235E+04  0.598E+01  0.109E+01     90.0
29 -0.320E+03  0.390E+05 -0.115E+03 -0.235E+04 -0.634E+01 -0.996E+00     90.0
30  0.241E+03  0.209E+05 -0.980E+02  0.235E+04 -0.621E+01 -0.305E+00     75.0
31  0.241E+03  0.209E+05 -0.980E+02  0.235E+04  0.621E+01  0.305E+00     75.0
32 -0.320E+03  0.390E+05 -0.115E+03 -0.235E+04  0.634E+01  0.996E+00     90.0
 1 -0.281E+03  0.391E+05 -0.594E+00 -0.235E+04  0.205E+01 -0.802E+01     90.0
 2  0.275E+03  0.209E+05 -0.107E+01  0.235E+04  0.204E+01 -0.800E+01     75.0
 3  0.275E+03  0.209E+05 -0.107E+01  0.235E+04 -0.204E+01  0.800E+01     75.0
 4 -0.281E+03  0.391E+05 -0.594E+00 -0.235E+04 -0.205E+01  0.802E+01     90.0
 5 -0.281E+03  0.391E+05 -0.646E+00 -0.235E+04  0.206E+01 -0.778E+01     90.0
 6  0.275E+03  0.209E+05 -0.117E+01  0.235E+04  0.206E+01 -0.781E+01     75.0
 7  0.275E+03  0.209E+05 -0.117E+01  0.235E+04 -0.206E+01  0.781E+01     75.0
 8 -0.281E+03  0.391E+05 -0.646E+00 -0.235E+04 -0.206E+01  0.778E+01     90.0
 9 -0.281E+03  0.391E+05  0.320E+00 -0.235E+04 -0.370E+00 -0.167E+01     90.0
10  0.275E+03  0.209E+05  0.274E+00  0.235E+04 -0.359E+00 -0.170E+01     75.0
11  0.275E+03  0.209E+05  0.274E+00  0.235E+04  0.359E+00  0.170E+01     75.0
12 -0.281E+03  0.391E+05  0.320E+00 -0.235E+04  0.370E+00  0.167E+01     90.0
13 -0.282E+03  0.391E+05  0.641E+01 -0.235E+04 -0.167E+00 -0.211E+01     90.0
14  0.274E+03  0.209E+05  0.552E+01  0.236E+04 -0.170E+00 -0.218E+01     75.0
15  0.274E+03  0.209E+05  0.552E+01  0.236E+04  0.170E+00  0.218E+01     75.0
16 -0.282E+03  0.391E+05  0.641E+01 -0.235E+04  0.167E+00  0.211E+01     90.0
17 -0.294E+03  0.391E+05 -0.422E+02 -0.236E+04 -0.238E+01 -0.128E+01     90.0
18  0.263E+03  0.209E+05 -0.361E+02  0.235E+04 -0.229E+01 -0.481E+00     75.0
19  0.263E+03  0.209E+05 -0.361E+02  0.235E+04  0.229E+01  0.481E+00     75.0
20 -0.294E+03  0.391E+05 -0.422E+02 -0.236E+04  0.238E+01  0.128E+01     90.0
21 -0.295E+03  0.390E+05 -0.416E+02 -0.235E+04 -0.202E+01 -0.119E+01     90.0
22  0.264E+03  0.209E+05 -0.356E+02  0.236E+04 -0.220E+01 -0.446E+00     75.0
23  0.264E+03  0.209E+05 -0.356E+02  0.236E+04  0.220E+01  0.446E+00     75.0
24 -0.295E+03  0.390E+05 -0.416E+02 -0.235E+04  0.202E+01  0.119E+01     90.0
```

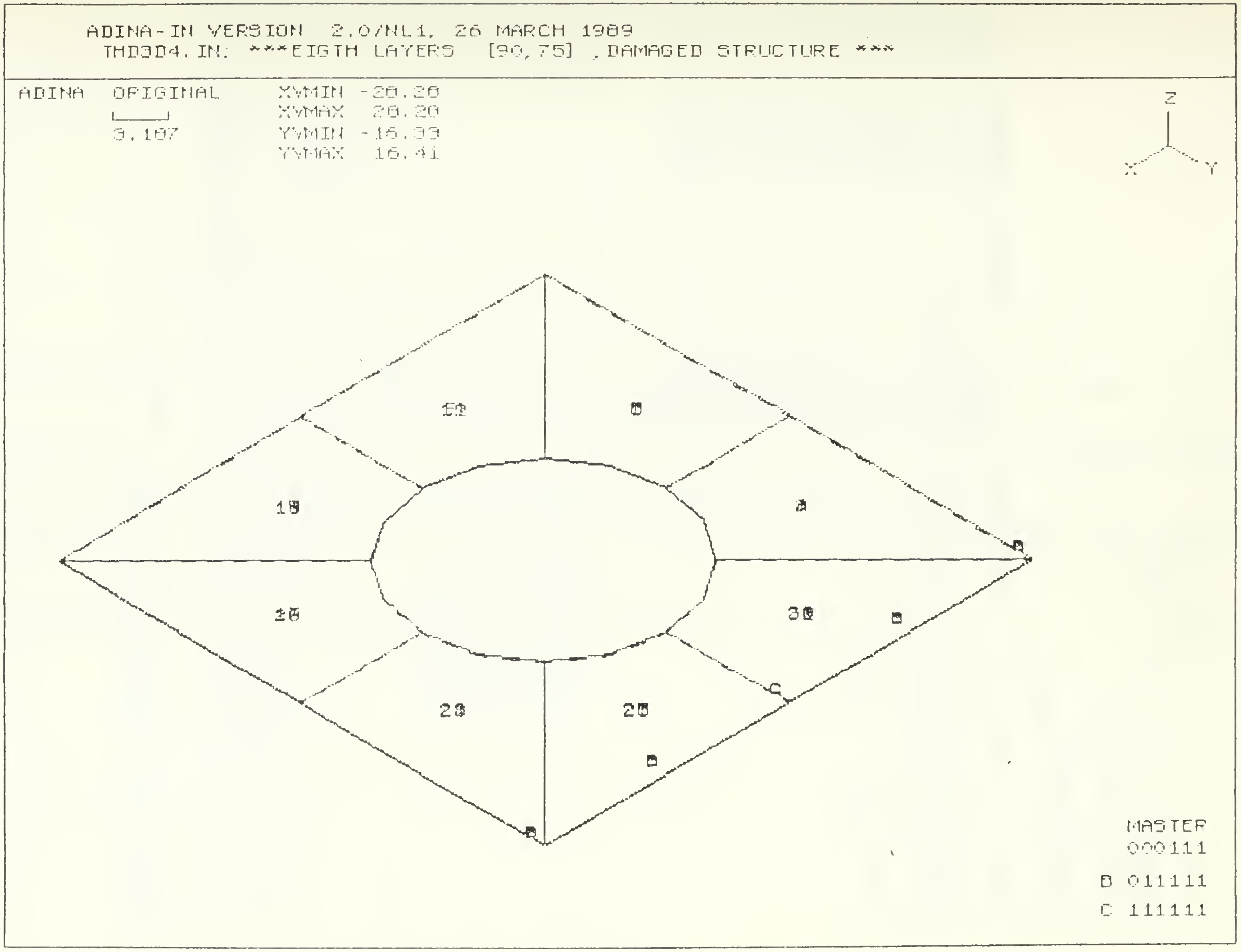
```
  25 -0.281E+03  0.391E+05  0.629E+01 -0.235E+04  0.323E+00  0.179E+01     90.0
  26  0.275E+03  0.209E+05  0.535E+01  0.235E+04  0.293E+00  0.211E+01     75.0
  27  0.275E+03  0.209E+05  0.535E+01  0.235E+04 -0.293E+00 -0.211E+01     75.0
  28 -0.281E+03  0.391E+05  0.629E+01 -0.235E+04 -0.323E+00 -0.179E+01     90.0
  29 -0.280E+03  0.391E+05  0.293E+00 -0.235E+04  0.130E+00  0.284E+01     90.0
  30  0.276E+03  0.209E+05  0.287E+00  0.235E+04  0.140E+00  0.243E+01     75.0
  31  0.276E+03  0.209E+05  0.287E+00  0.235E+04 -0.140E+00 -0.243E+01     75.0
  32 -0.280E+03  0.391E+05  0.293E+00 -0.235E+04 -0.130E+00 -0.284E+01     90.0

 NEL     S1         S2         S3         S6         S5         S4
-------------------------------------------------------------------------

   1  0.391E+05 -0.277E+03  0.187E+02  0.235E+04  0.622E+01 -0.909E+00
   2  0.207E+05  0.485E+03  0.160E+02  0.313E+04  0.605E+01  0.743E+00
   3  0.207E+05  0.485E+03  0.160E+02  0.313E+04 -0.605E+01 -0.743E+00
   4  0.391E+05 -0.277E+03  0.187E+02  0.235E+04 -0.622E+01  0.909E+00
   5  0.391E+05 -0.278E+03  0.248E+01  0.235E+04  0.675E+01 -0.399E+00
   6  0.207E+05  0.486E+03  0.217E+01  0.313E+04  0.669E+01  0.142E+01
   7  0.207E+05  0.486E+03  0.217E+01  0.313E+04 -0.669E+01 -0.142E+01
   8  0.391E+05 -0.278E+03  0.248E+01  0.235E+04 -0.675E+01  0.399E+00
   9  0.391E+05 -0.278E+03  0.653E-01  0.235E+04 -0.216E+02 -0.552E+01
  10  0.207E+05  0.485E+03 -0.746E+00  0.313E+04 -0.194E+02 -0.109E+02
  11  0.207E+05  0.485E+03 -0.746E+00  0.313E+04  0.194E+02  0.109E+02
  12  0.391E+05 -0.278E+03  0.653E-01  0.235E+04  0.216E+02  0.552E+01
  13  0.391E+05 -0.278E+03  0.113E+00  0.235E+04 -0.210E+02 -0.559E+01
  14  0.207E+05  0.485E+03 -0.692E+00  0.313E+04 -0.189E+02 -0.108E+02
  15  0.207E+05  0.485E+03 -0.692E+00  0.313E+04  0.189E+02  0.108E+02
  16  0.391E+05 -0.278E+03  0.113E+00  0.235E+04  0.210E+02  0.559E+01
  17  0.391E+05 -0.278E+03  0.250E+01  0.235E+04 -0.434E+01  0.992E+00
  18  0.207E+05  0.485E+03  0.218E+01  0.313E+04 -0.448E+01 -0.198E+00
  19  0.207E+05  0.485E+03  0.218E+01  0.313E+04  0.448E+01  0.198E+00
  20  0.391E+05 -0.278E+03  0.250E+01  0.235E+04  0.434E+01 -0.992E+00
```

```
21  0.391E+05 -0.278E+03  0.190E+02  0.236E+04 -0.566E+01  0.608E+00
22  0.207E+05  0.486E+03  0.163E+02  0.313E+04 -0.568E+01 -0.952E+00
23  0.207E+05  0.486E+03  0.163E+02  0.313E+04  0.568E+01  0.952E+00
24  0.391E+05 -0.278E+03  0.190E+02  0.236E+04  0.566E+01 -0.608E+00
25  0.390E+05 -0.318E+03 -0.115E+03  0.235E+04 -0.109E+01  0.598E+01
26  0.207E+05  0.450E+03 -0.982E+02  0.313E+04 -0.197E+01  0.575E+01
27  0.207E+05  0.450E+03 -0.982E+02  0.313E+04  0.197E+01 -0.575E+01
28  0.390E+05 -0.318E+03 -0.115E+03  0.235E+04  0.109E+01 -0.598E+01
29  0.390E+05 -0.320E+03 -0.115E+03  0.235E+04 -0.996E+00  0.634E+01
30  0.207E+05  0.449E+03 -0.980E+02  0.313E+04 -0.190E+01  0.592E+01
31  0.207E+05  0.449E+03 -0.980E+02  0.313E+04  0.190E+01 -0.592E+01
32  0.390E+05 -0.320E+03 -0.115E+03  0.235E+04  0.996E+00 -0.634E+01
33  0.391E+05 -0.281E+03 -0.594E+00  0.235E+04 -0.802E+01 -0.205E+01
34  0.207E+05  0.482E+03 -0.107E+01  0.313E+04 -0.720E+01 -0.404E+01
35  0.207E+05  0.482E+03 -0.107E+01  0.313E+04  0.720E+01  0.404E+01
36  0.391E+05 -0.281E+03 -0.594E+00  0.235E+04  0.802E+01  0.205E+01
37  0.391E+05 -0.281E+03 -0.646E+00  0.235E+04 -0.778E+01 -0.206E+01
38  0.207E+05  0.482E+03 -0.117E+01  0.313E+04 -0.701E+01 -0.401E+01
39  0.207E+05  0.482E+03 -0.117E+01  0.313E+04  0.701E+01  0.401E+01
40  0.391E+05 -0.281E+03 -0.646E+00  0.235E+04  0.778E+01  0.206E+01
41  0.391E+05 -0.281E+03  0.320E+00  0.235E+04 -0.167E+01  0.370E+00
42  0.207E+05  0.482E+03  0.274E+00  0.313E+04 -0.173E+01 -0.927E-01
43  0.207E+05  0.482E+03  0.274E+00  0.313E+04  0.173E+01  0.927E-01
44  0.391E+05 -0.281E+03  0.320E+00  0.235E+04  0.167E+01 -0.370E+00
45  0.391E+05 -0.282E+03  0.641E+01  0.235E+04 -0.211E+01  0.167E+00
46  0.207E+05  0.481E+03  0.552E+01  0.313E+04 -0.215E+01 -0.401E+00
47  0.207E+05  0.481E+03  0.552E+01  0.313E+04  0.215E+01  0.401E+00
48  0.391E+05 -0.282E+03  0.641E+01  0.235E+04  0.211E+01 -0.167E+00
49  0.391E+05 -0.294E+03 -0.422E+02  0.235E+04 -0.128E+01  0.238E+01
50  0.207E+05  0.471E+03 -0.361E+02  0.313E+04 -0.106E+01  0.208E+01
```

```
     51  0.207E+05  0.471E+03 -0.361E+02  0.313E+04  0.106E+01 -0.208E+01
     52  0.391E+05 -0.294E+03 -0.422E+02  0.235E+04  0.128E+01 -0.238E+01
     53  0.390E+05 -0.295E+03 -0.416E+02  0.235E+04 -0.119E+01  0.202E+01
     54  0.207E+05  0.470E+03 -0.356E+02  0.313E+04 -0.100E+01  0.201E+01
     55  0.207E+05  0.470E+03 -0.356E+02  0.313E+04  0.100E+01 -0.201E+01
     56  0.390E+05 -0.295E+03 -0.416E+02  0.235E+04  0.119E+01 -0.202E+01
     57  0.391E+05 -0.281E+03  0.629E+01  0.235E+04  0.179E+01 -0.323E+00
     58  0.207E+05  0.482E+03  0.535E+01  0.313E+04  0.212E+01  0.264E+00
     59  0.207E+05  0.482E+03  0.535E+01  0.313E+04 -0.212E+01 -0.264E+00
     60  0.391E+05 -0.281E+03  0.629E+01  0.235E+04 -0.179E+01  0.323E+00
     61  0.391E+05 -0.280E+03  0.293E+00  0.235E+04  0.284E+01 -0.130E+00
     62  0.207E+05  0.483E+03  0.287E+00  0.313E+04  0.238E+01  0.493E+00
     63  0.207E+05  0.483E+03  0.287E+00  0.313E+04 -0.238E+01 -0.493E+00
     64  0.391E+05 -0.280E+03  0.293E+00  0.235E+04 -0.284E+01  0.130E+00
ALFA :    5.000000
     NEL      R1         R2         R3         R6         R5         R4         RE
-----------------------------------------------------------------------------------------

       1  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
       2  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
       3  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
       4  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
       5  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
       6  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
       7  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
       8  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
       9  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
      10  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
      11  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
      12  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
      13  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
```

```
14  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
15  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
16  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
17  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
18  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
19  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
20  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
21  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
22  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
23  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
24  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
25  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
26  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
27  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
28  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
29  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
30  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
31  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
32  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.998E+00
33  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
34  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
35  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
36  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
37  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
38  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
39  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
40  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
41  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
42  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
43  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
```

```
     44  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     45  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     46  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     47  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     48  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     49  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     50  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     51  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     52  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     53  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     54  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     55  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     56  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     57  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     58  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     59  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     60  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     61  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

     62  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     63  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00

     64  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00

TOTAL REL.    RT1        RT2        RT3        RT6        RT5        RT4        RT
--------------------------------------------------------------------------------------

           0.991E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.824E+00

TOTAL STRUCTURE RELIABILITY =   0.824E+00
=====================================
```


ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THD3D4.IN: ***EIGTH LAYERS [90,75] ,DAMAGED STRUCTURE ***
ADINA ORIGINAL
3.107
XVMIN -20.20
XVMAX 20.20
YVMIN -16.39
YVMAX 16.41
Z
X
Y
C
MASTER
000111
B 011111
C 111111

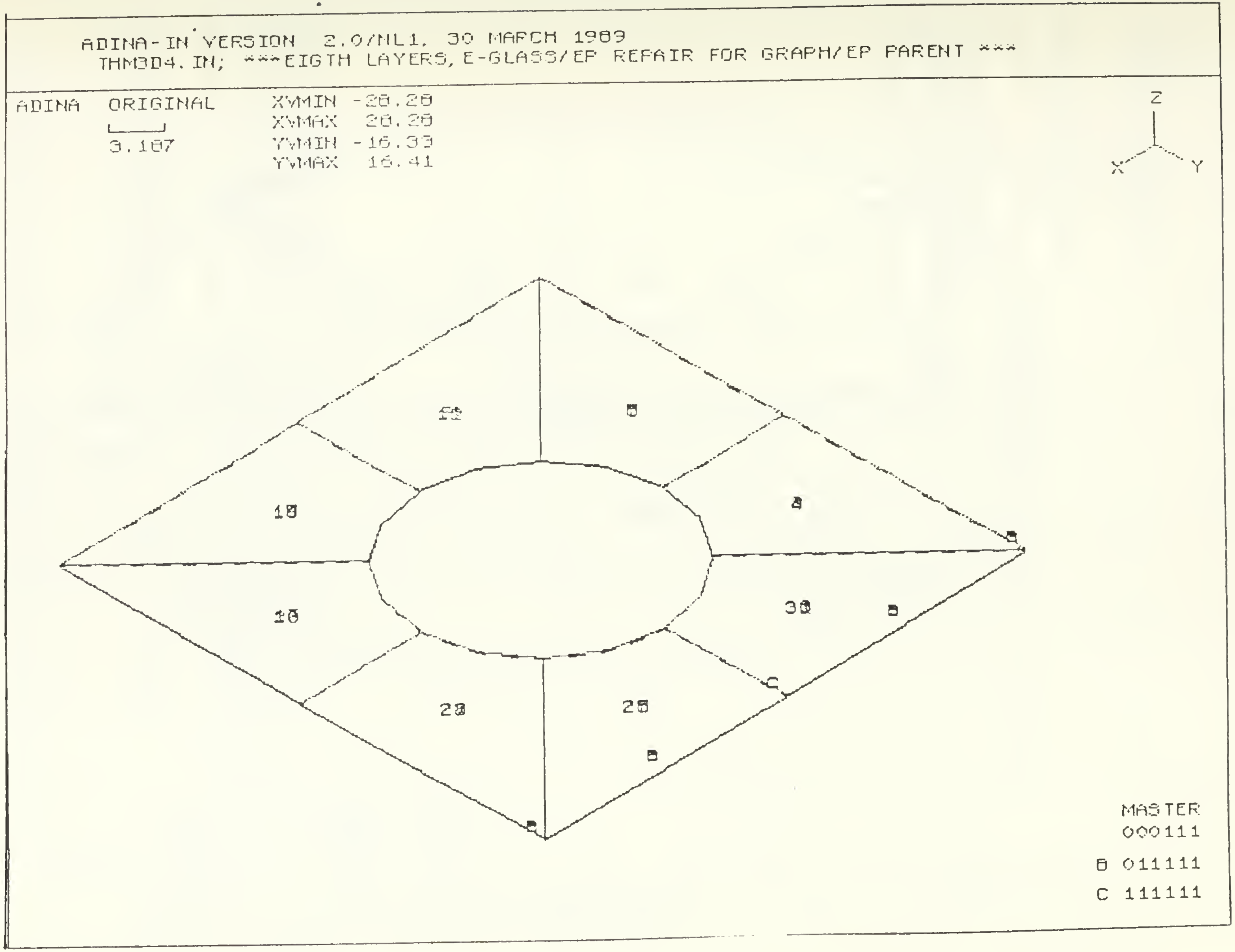
```
*        A D I N A - I N   I N P U T   F I L E
*
* THD3D4.IN EIGHT SYMMETRIC LAYER USING 3-D.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THD3D4.IN; ***EIGTH LAYERS  [90,75] ,DAMAGED STRUCTURE ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE     X      Y     Z
                        1    -20.   -20.  0.1
                        2      0.   -20.  0.1
                        3     20.   -20.  0.1
                        4    -20.     0.  0.1
                        5      0.     0.  0.1
                        6     20.     0.  0.1
                        7    -20.    20.  0.1
                        8      0.    20.  0.1
                        9     20.    20.  0.1
                        21   -20.   -20.  0.
                        22     0.   -20.  0.
                        23    20.   -20.  0.
                        24   -20.     0.  0.
                        25     0.     0.  0.
                        26    20.     0.  0.
                        27   -20.    20.  0.
                        28     0.    20.  0.
                        29    20.    20.  0.
                      101      5.     0.  0.
                      102      0.    10.  0.
                      103      5.    10.  0.
                      104     15.     2.68 0.
                      105      7.68  10.   0.
                      106     15.    10.   0.
                      107     15.   -10.   0.
*=====================================================
*NOTE THE MAXES MEAN : 1=90DEG 2=15 3=75 4=45 5=-45
*======================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                        GAB=7.17E05 7.17E05 7.17E05
*
SYSTEM 1 CYLINDRIC X=0 Y=0 Z=0 PHI=0 THETA=-90. XSI=90.
COORDINATES / ENTRIES NODES R THETA      XL
                       10    10.  0.      0.1
                       11    10.  45.     0.1
                       12    10.  90.     0.1
                       13    10.  135.    0.1
                       14    10.  180.    0.1
                       15    10.  225.    0.1
                       16    10.  270.    0.1
                       17    10.  315.    0.1
                      18    10.  360.   0.1
                      30    10.  0.     0.
                      31    10.  45.    0.
                      32    10.  90.    0.
                      33    10.  135.   0.
                      34    10.  180.   0.
                      35    10.  225.   0.
                      36    10.  270.   0.
                      37    10.  315.   0.
                      38    10.  360.   0.
*
LINE CYLINDRIC 11 10 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 12 11 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 13 12 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 14 13 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 15 14 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 16 15 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 17 16 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 18 17 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 31 30 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 32 31 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 33 32 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 34 33 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 35 34 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 36 35 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 37 36 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 38 37 EL=1 MIDNODES=1 NC=A
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 7 4 18 17 27 24 38 37 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 4 1 11 10 24 21 31 30 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 1 2 12 11 21 22 32 31 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 2 3 13 12 22 23 33 32 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 3 6 14 13 23 26 34 33 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 6 9 15 14 26 29 35 34 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 8 16 15 29 28 36 35 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 8 7 17 16 28 27 37 36 EL1=1 EL2=1 EL3=4 NODES=27
GSURFACE 7 8 28 27   EL1=1 EL2=4 NO=9
GSURFACE 8 9 29 28   EL1=1 EL2=4 NO=9
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                 1     1      1
  STEP 4 TO
                 29    1      1
                 2     1      3
  STEP 4 TO
                 30    1      3
                 3     1      3
  STEP 4 TO
                 31    1      3
                 4     1      1
  STEP 4 TO
                 32    1      1
*
```

```
LOADS ELEMENT
              9  2  -3.0E04
         TO
              16  2  -3.0E04

*
FIXB 123 LINES / 8 28
FIXB 23 SURFACES /  7 8 28 27 / 8 9 29 28
*
*
EGZONE NAME=PARENT / 1
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=PARENT NODES=0 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

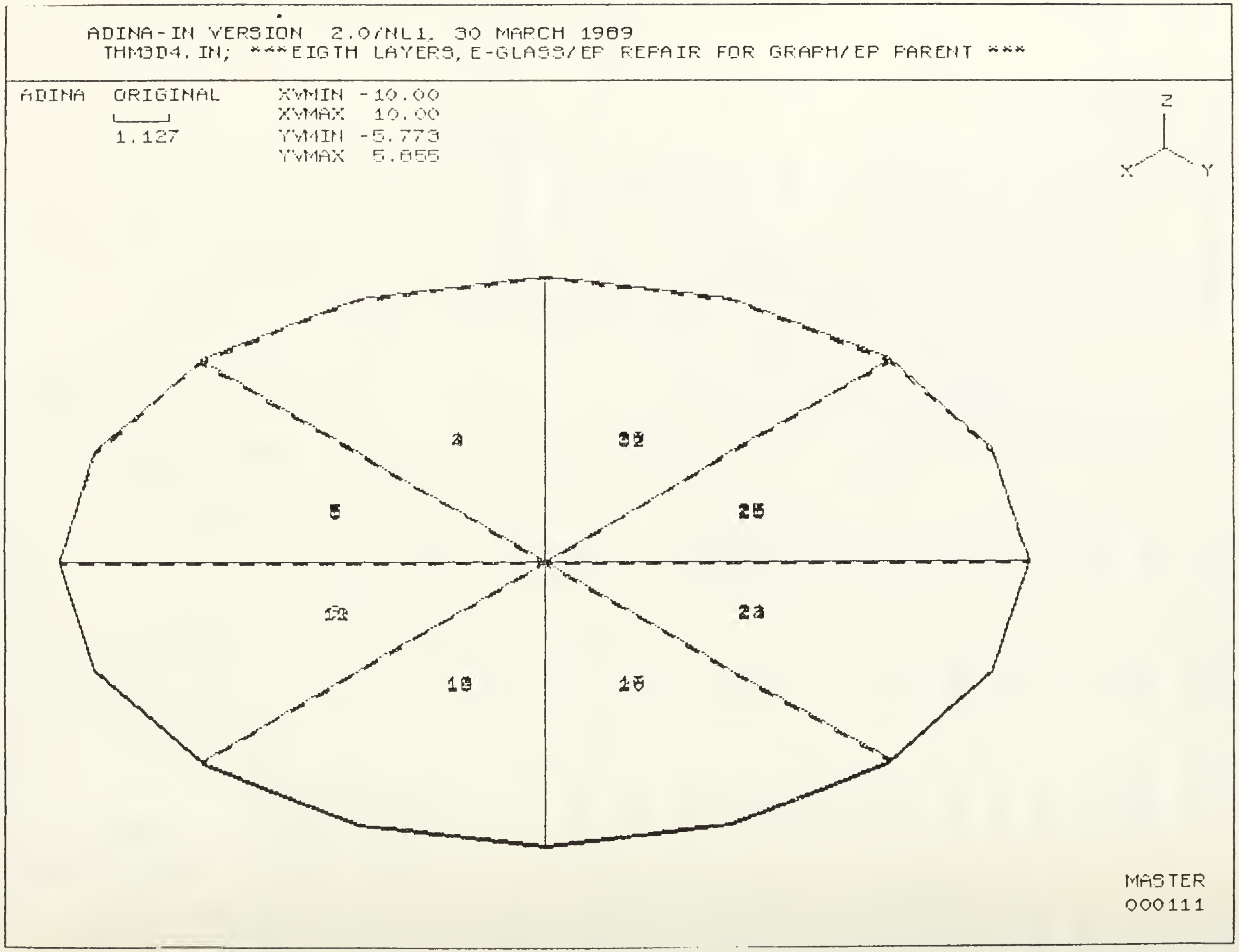
```
INPUT STRESS FN = THD3D4.STR
INPUT ELEM. ANGLE FN = THD3D4.EL
INPUT  AREAS OF ELEMENTS FN =THD3D4.ARE
 OUTPUT FN =THD3D4.REL
OUTPUT :THD3D4.REL

      NEL     SX          SY          SZ          SXY         SXZ         SYZ      ANGLE
-------------------------------------------------------------------------------

        1 -0.136E+04  0.660E+05  0.477E+02 -0.669E+04  0.161E+01 -0.203E+02      90.0

        2 -0.220E+04  0.199E+05  0.496E+02 -0.279E+04 -0.422E+01 -0.381E+02      75.0

        3 -0.220E+04  0.199E+05  0.496E+02 -0.279E+04  0.422E+01  0.381E+02      75.0

        4 -0.136E+04  0.660E+05  0.477E+02 -0.669E+04 -0.161E+01  0.203E+02      90.0

        5  0.322E+04  0.725E+05  0.120E+03 -0.688E+04  0.267E+02  0.119E+02      90.0

        6  0.326E+04  0.291E+05  0.119E+03 -0.245E+03  0.105E+01  0.110E+02      75.0

        7  0.326E+04  0.291E+05  0.119E+03 -0.245E+03 -0.105E+01 -0.110E+02      75.0

        8  0.322E+04  0.725E+05  0.120E+03 -0.688E+04 -0.267E+02 -0.119E+02      90.0

        9  0.409E+04  0.343E+05 -0.165E+03 -0.542E+04  0.774E+02 -0.334E+02      90.0

       10  0.319E+04  0.478E+04 -0.113E+03 -0.427E+04  0.115E+02  0.387E+01      75.0

       11  0.319E+04  0.478E+04 -0.113E+03 -0.427E+04 -0.115E+02 -0.387E+01      75.0

       12  0.409E+04  0.343E+05 -0.165E+03 -0.542E+04 -0.774E+02  0.334E+02      90.0

       13  0.168E+04  0.145E+05 -0.985E+02  0.181E+04 -0.421E+02 -0.409E+02      90.0

       14  0.376E+04  0.240E+05 -0.156E+03  0.792E+04  0.977E+01 -0.744E+01      75.0

       15  0.376E+04  0.240E+05 -0.156E+03  0.792E+04 -0.977E+01  0.744E+01      75.0

       16  0.168E+04  0.145E+05 -0.985E+02  0.181E+04  0.421E+02  0.409E+02      90.0

       17  0.132E+04  0.444E+05  0.149E+03 -0.180E+04 -0.172E+02  0.362E+02      90.0

       18  0.271E+04  0.301E+05  0.152E+03  0.533E+04  0.518E+01  0.432E+02      75.0

       19  0.271E+04  0.301E+05  0.152E+03  0.533E+04 -0.518E+01 -0.432E+02      75.0

       20  0.132E+04  0.444E+05  0.149E+03 -0.180E+04  0.172E+02 -0.362E+02      90.0

       21 -0.342E+02  0.607E+05  0.257E+02 -0.126E+04 -0.969E+01  0.169E+02      90.0

       22  0.234E+04  0.458E+05  0.148E+02  0.948E+04  0.214E+01  0.727E+01      75.0

       23  0.234E+04  0.458E+05  0.148E+02  0.948E+04 -0.214E+01 -0.727E+01      75.0

       24 -0.342E+02  0.607E+05  0.257E+02 -0.126E+04  0.969E+01 -0.169E+02      90.0

       25 -0.440E+04  0.238E+05  0.169E+03 -0.125E+04 -0.836E+01  0.377E+02      90.0
```

```
   26 -0.456E+04  0.950E+04  0.196E+03  0.298E+03 -0.589E+01 -0.127E+01       75.0
   27 -0.456E+04  0.950E+04  0.196E+03  0.298E+03  0.589E+01  0.127E+01       75.0
   21  0.238E+05  0.169E+03 -0.125E+04  0.836E+01 -0.377E+02 -0.469E-02       90.0
   29 -0.410E+04  0.265E+05 -0.145E+03 -0.193E+04 -0.202E+02  0.241E+02       90.0
   30 -0.447E+04  0.858E+04 -0.126E+03 -0.600E+03 -0.943E+01 -0.503E+01       75.0
   31 -0.447E+04  0.858E+04 -0.126E+03 -0.600E+03  0.943E+01  0.503E+01       75.0
   32 -0.410E+04  0.265E+05 -0.145E+03 -0.193E+04  0.202E+02 -0.241E+02       90.0

   NEL     S1          S2          S3          S6          S5          S4
-------------------------------------------------------------------------------

    1  0.660E+05 -0.136E+04  0.477E+02  0.669E+04 -0.203E+02 -0.161E+01
    2  0.171E+05  0.677E+03  0.496E+02  0.795E+04 -0.379E+02 -0.578E+01
    3  0.171E+05  0.677E+03  0.496E+02  0.795E+04  0.379E+02  0.578E+01
    4  0.660E+05 -0.136E+04  0.477E+02  0.669E+04  0.203E+02  0.161E+01
    5  0.725E+05  0.322E+04  0.120E+03  0.688E+04  0.119E+02 -0.267E+02
    6  0.272E+05  0.511E+04  0.119E+03  0.666E+04  0.109E+02  0.184E+01
    7  0.272E+05  0.511E+04  0.119E+03  0.666E+04 -0.109E+02 -0.184E+01
    8  0.725E+05  0.322E+04  0.120E+03  0.688E+04 -0.119E+02  0.267E+02
    9  0.343E+05  0.409E+04 -0.165E+03  0.542E+04 -0.334E+02 -0.774E+02
   10  0.254E+04  0.543E+04 -0.113E+03  0.410E+04  0.671E+01 -0.101E+02
   11  0.254E+04  0.543E+04 -0.113E+03  0.410E+04 -0.671E+01  0.101E+02
   12  0.343E+05  0.409E+04 -0.165E+03  0.542E+04  0.334E+02  0.774E+02
   13  0.145E+05  0.168E+04 -0.985E+02 -0.181E+04 -0.409E+02  0.421E+02
   14  0.266E+05  0.116E+04 -0.156E+03 -0.180E+04 -0.465E+01 -0.114E+02
   15  0.266E+05  0.116E+04 -0.156E+03 -0.180E+04  0.465E+01  0.114E+02
   16  0.145E+05  0.168E+04 -0.985E+02 -0.181E+04  0.409E+02 -0.421E+02
   17  0.444E+05  0.132E+04  0.149E+03  0.180E+04  0.362E+02  0.172E+02
   18  0.309E+05  0.188E+04  0.152E+03  0.223E+04  0.430E+02  0.617E+01
   19  0.309E+05  0.188E+04  0.152E+03  0.223E+04 -0.430E+02 -0.617E+01
   20  0.444E+05  0.132E+04  0.149E+03  0.180E+04 -0.362E+02 -0.172E+02
   21  0.607E+05 -0.342E+02  0.257E+02  0.126E+04  0.169E+02  0.969E+01
```

```
         22  0.476E+05  0.507E+03  0.148E+02  0.265E+04  0.757E+01 -0.187E+00
         23  0.476E+05  0.507E+03  0.148E+02  0.265E+04 -0.757E+01  0.187E+00
         24  0.607E+05 -0.342E+02  0.257E+02  0.126E+04 -0.169E+02 -0.969E+01
         25  0.238E+05 -0.440E+04  0.169E+03  0.125E+04  0.377E+02  0.836E+01
         26  0.870E+04 -0.377E+04  0.196E+03  0.326E+04 -0.276E+01  0.536E+01
         27  0.870E+04 -0.377E+04  0.196E+03  0.326E+04  0.276E+01 -0.536E+01
         28  0.169E+03  0.238E+05 -0.125E+04 -0.836E+01 -0.468E-02  0.377E+02
         29  0.265E+05 -0.410E+04 -0.145E+03  0.193E+04  0.241E+02  0.202E+02
         30  0.741E+04 -0.330E+04 -0.126E+03  0.378E+04 -0.730E+01  0.781E+01
         31  0.741E+04 -0.330E+04 -0.126E+03  0.378E+04  0.730E+01 -0.781E+01
         32  0.265E+05 -0.410E+04 -0.145E+03  0.193E+04 -0.241E+02 -0.202E+02

ALFA :   5.000000
         NEL      R1         R2         R3         R6         R5         R4         RE
-------------------------------------------------------------------------------------------

          1  0.993E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.668E+00  0.663E+00
          2  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.384E+00  0.384E+00
          3  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.384E+00  0.384E+00
          4  0.993E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.668E+00  0.663E+00
          5  0.992E+00  0.906E+00  0.100E+01  0.100E+01  0.100E+01  0.735E+00  0.661E+00
          6  0.100E+01  0.372E+00  0.100E+01  0.100E+01  0.100E+01  0.769E+00  0.286E+00
          7  0.100E+01  0.372E+00  0.100E+01  0.100E+01  0.100E+01  0.769E+00  0.286E+00
          8  0.992E+00  0.906E+00  0.100E+01  0.100E+01  0.100E+01  0.735E+00  0.661E+00
          9  0.100E+01  0.614E+00  0.100E+01  0.100E+01  0.100E+01  0.869E+00  0.533E+00
         10  0.100E+01  0.133E+00  0.100E+01  0.100E+01  0.100E+01  0.966E+00  0.129E+00
         11  0.100E+01  0.133E+00  0.100E+01  0.100E+01  0.100E+01  0.966E+00  0.129E+00
         12  0.100E+01  0.614E+00  0.100E+01  0.100E+01  0.100E+01  0.869E+00  0.533E+00
         13  0.100E+01  0.996E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.996E+00
         14  0.100E+01  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
         15  0.100E+01  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00
         16  0.100E+01  0.996E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.996E+00
         17  0.999E+00  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.997E+00

         18  0.100E+01  0.990E+00  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.988E+00

         19  0.100E+01  0.990E+00  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.988E+00

         20  0.999E+00  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.997E+00

         21  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.997E+00

         22  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.997E+00  0.996E+00

         23  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.997E+00  0.996E+00

         24  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.997E+00

         25  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01

         26  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.989E+00  0.989E+00

         27  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.989E+00  0.989E+00

         28  0.100E+01  0.000E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.000E+00

         29  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00

         30  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.985E+00  0.985E+00

         31  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.985E+00  0.985E+00

         32  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00

TOTAL REL.    RT1        RT2        RT3        RT6        RT5        RT4         RT
-----------------------------------------------------------------------------------------

              0.960E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00

TOTAL STRUCTURE RELIABILITY =   0.000E+00
========================================
```



```
ADINA-IN VERSION  2.0/NL1, 30 MARCH 1989
 THM3D4.IN; ***EIGTH LAYERS, E-GLASS/EP REFAIR FOR GRAPH/EP PARENT ***

ADINA  ORIGINAL      XVMIN -20.20
                     XVMAX  20.20
       3.107         YVMIN -16.33
                     YVMAX  16.41
```


ADINA-IN VERSION 2.0/NL1, 30 MARCH 1989
THM3D4.IN; ***EIGTH LAYERS, E-GLASS/EP REPAIR FOR GRAPH/EP PARENT ***
ADINA
ORIGINAL
1.127
XVMIN -10.00
XVMAX 10.00
YVMIN -5.773
YVMAX 5.855
Z
X
Y
4
32
5
25
12
23
18
16
MASTER
000111

```
*        A D I N A - I N    I N P U T    F I L E
*
* THM3D4.IN EIGHT SYMMETRIC LAYER USING 3-D.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THM3D4.IN; ***EIGHT LAYERS SOLUTION  90,75 DEG ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE     X      Y     Z
                           1     -20.   -20.  0.1
                           2       0.   -20.  0.1
                           3      20.   -20.  0.1
                           4     -20.     0.  0.1
                           5       0.     0.  0.1
                           6      20.     0.  0.1
                           7     -20.    20.  0.1
                           8       0.    20.  0.1
                           9      20.    20.  0.1
                           21    -20.   -20.  0.
                           22      0.   -20.  0.
                           23     20.   -20.  0.
                           24    -20.     0.  0.
                           25      0.     0.  0.
                           26     20.     0.  0.
                           27    -20.    20.  0.
                           28      0.    20.  0.
                           29     20.    20.  0.
                         101       5.     0.  0.
                         102       0.    10.  0.
                         103       5.    10.  0.
                         104      15.      2.68 0.
                         105       7.68  10.    0.
                         106      15.    10.    0.
                         107      15.   -10.    0.
*=====================================================
*NOTE THE MAXES MEAN : 1=90DEG 2=15 3=75 4=45 5=-45
*=====================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                        GAB=7.17E05 7.17E05 7.17E05
MATERIAL 2 ORTHOTROPIC 53.8E05 17.9E05 17.9E05 0.083 0.083 0.25,
                        GAB=8.6E05 8.6E05 8.6E05
*
SYSTEM 1 CYLINDRIC X=0 Y=0 Z=0 PHI=0 THETA=-90. XSI=90.
COORDINATES / ENTRIES NODES R THETA      XL
                        10    10.  0.       0.1
                        11    10.  45.      0.1
                        12    10.  90.      0.1
                        13    10.  135.     0.1
                        14    10.  180.     0.1
                        15    10.  225.     0.1
                        16    10.  270.   0.1
                        17    10.  315.   0.1
                        18    10.  360.   0.1
                        30    10.  0.     0.
                        31    10.  45.    0.
                        32    10.  90.    0.
                        33    10.  135.   0.
                        34    10.  180.   0.
                        35    10.  225.   0.
                        36    10.  270.   0.
                        37    10.  315.   0.
                        38    10.  360.   0.
*
LINE CYLINDRIC 11 10 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 12 11 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 13 12 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 14 13 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 15 14 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 16 15 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 17 16 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 18 17 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 31 30 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 32 31 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 33 32 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 34 33 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 35 34 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 36 35 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 37 36 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 38 37 EL=1 MIDNODES=1 NC=A
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 7 4 18 17 27 24 38 37 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 4 1 11 10 24 21 31 30 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 1 2 12 11 21 22 32 31 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 2 3 13 12 22 23 33 32 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 3 6 14 13 23 26 34 33 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 6 9 15 14 26 29 35 34 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 8 16 15 29 28 36 35 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 8 7 17 16 28 27 37 36 EL1=1 EL2=1 EL3=4 NODES=27
GSURFACE 7 8 28 27   EL1=1 EL2=4 NO=9
GSURFACE 8 9 29 28   EL1=1 EL2=4 NO=9
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1     1      1
  STEP 4 TO
                29    1      1
                2     1      3
  STEP 4 TO
                30    1      3
                3     1      3
  STEP 4 TO
                31    1      3
                4     1      1
  STEP 4 TO
```

```
               32    1      1
*
LOADS ELEMENT
              9  2  -3.0E04
        TO
             16  2  -3.0E04

*
FIXB 123 LINES / 8 28
FIXB 23 SURFACES /  7 8 28 27 / 8 9 29 28
*
*
EGROUP 2 THREEDSOLID MATERIAL=2 TABLES
GVOLUME 11 12 5 5 31 32 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 12 13 5 5 32 33 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 13 14 5 5 33 34 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 14 15 5 5 34 35 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 15 16 5 5 35 36 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 16 17 5 5 36 37 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 17 18 5 5 37 38 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 10 11 5 5 30 31 25 25 EL1=1 EL2=1 EL3=4 NODES=27
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
               1     1      1
  STEP 4 TO
               29    1      1
               2     1      3
  STEP 4 TO
               30    1      3
               3     1      3
  STEP 4 TO
               31    1      3
               4     1      1
  STEP 4 TO
               32    1      1
*
*
EGZONE NAME=PARENT / 1
EGZONE NAME=PATCH / 2
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=PARENT NODES=0 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
FRAME HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=PATCH NODES=0 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

```
*********************************************************
      PROGRAM TRANS3
*********************************************************
C     THIS PROGRAM TRANFORMS THE STRESSES OUTPUT FROM ADINA,
C     EXPRESSED IN THE GLOBAL STRUCTURE COORDINATE SYSTEM, TO
C     THE PRINCIPAL MATERIAL COORDINATE. AND THEN, CALCULATES THE
C     RELIABILTY PER STRESS COMPONENT AND PER ELEMENT AND FINALLY
C     EVALUATES THE TOTAL RELIABILITY. ALL THAT BY CALLING THE
C     SUBROUTINE HEREIN.
C     NEL            : # OF WHOLE SRUCTURE ELEMENTS.
C     NELP           : # OF PARENT STRUCTURE ELEMENTS
C     SX,SY,...,SYZ  : THE STRESS IN GLOBAL COORDINATE SYSTEM.
C     THETA          : THE LAYUP ANGLE PER ELEMENT.
C     S1,S2,... S6   : THE STRESS IN THE MATERIAL PRINCIPAL COORDINATE.
C     R1,R2,...,R6   : THE RELIABILITY PER STRESS COMPONENT.
C     RT1,RT2,...RT6: THE TOTAL RELIABILTY OF STRUCTURE PER COPMPONENT.
C     RE             : THE RELIABILITY PER ELEMENT
C     RT             : THE TOTAL RELIABILITY.
C     ALF            : THE SHAPE FUNCTION PARAMER FOR WEIBULL
C     BEFORE RUNNING THE PROGRAM VERIFY IN THE PROGRAM THE ANGLE THETA
C     INPUT AND THE # OF ELEMENT.AND ALSO VERIFY THE MATERIAL PROEPRTIES
C     GIVEN IN SUBROUTINE BETA.
************************************************************************
      INTEGER NEL
      PARAMETER (NEL=64,NELP=32,PI = 3.1415927 )
      PARAMETER (ROWS=100,COLS=6,COLS1=7)
      INTEGER ITHETA(NEL)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS),C(ROWS,COLS1)
      REAL SX(NEL),SY(NEL),SZ(NEL),SXY(NEL),SXZ(NEL),SYZ(NEL)
      REAL L,M,THETA(NEL),THETAF(NEL),ALF
      CHARACTER*20 FNAME,FNOUT,FNAME1,FNAME2
*
      WRITE (5,*) 'ENTER INPUT STRESS FN  ?'
      READ (5,'(A)') FNAME
      WRITE (5,*) 'INPUT STRESS FN = ',FNAME
      OPEN (UNIT=15,FILE=FNAME,STATUS='OLD')
      WRITE (5,*) 'ENTER INPUT ELEM. ANGLE FN?'
      READ (5,'(A)') FNAME2
      WRITE (5,*) 'INPUT ELEM. ANGLE FN = ',FNAME2
      OPEN (UNIT=16,FILE=FNAME2,STATUS='OLD')
      WRITE (5,*) 'ENTER AREAS OF ELEMENTS FN ?'
      READ (5,'(A)') FNAME1
      OPEN (UNIT=17,FILE=FNAME1,STATUS='OLD')
      WRITE (5,*) ' ENTER OUTPUT FN ?'
      READ (5,'(A)') FNOUT
      OPEN (UNIT=13,FILE=FNOUT,STATUS='NEW')
      WRITE (13,*) 'INPUT STRESS FN = ',FNAME
      WRITE (13,*) 'INPUT ELEM. ANGLE FN = ',FNAME2
      WRITE (13,*) 'INPUT  AREAS OF ELEMENTS FN =',FNAME1
      WRITE (13,*) ' OUTPUT FN =',FNOUT
*
*INPUT OF ANGLE (THETA) FOR EA. ELEMENT ;
*---------------------------------------
      DO 20 I=1,NEL
      READ (16,*) N,I2,I3,I4,I5,I6,ITHETA(I),I8,A9,A10,I11,
     &            I12,I13,I14,I15,I16,I17,I18,I19
        IF (ITHETA(I).EQ.1) THETA(I) = 90.0
        IF (ITHETA(I).EQ.3) THETA(I) = 75.0
        WRITE (5,25) N,THETA(I)
         THETAF(I) = THETA(I)* PI/180.0
```

```
20    CONTINUE
*
      WRITE (13,*) 'OUTPUT :',FNOUT
*
*TRANSFORMATION OF STRESSES TO PRINCIPAL AXES STRESS ;
*------------------------------------------------------------
      WRITE (13,11) 'NEL','SX','SY', 'SZ','SXY','SXZ','SYZ','ANGLE'
      DO 55 I=1,NEL
      READ (15,*) IEL,NOD,SX(I),SY(I),SZ(I),SXY(I),SXZ(I),SYZ(I)
      THETA(I) = THETAF(I)*180.0 / PI
      WRITE (13,61) IEL,SX(I),SY(I),SZ(I),SXY(I),SXZ(I),SYZ(I),
     &                 THETA(I)

*
      L=COS(THETAF(I))
      M=SIN(THETAF(I))
        A(I,1)= SX(I)*(L**2) + SY(I)*(M**2) + 2*SXY(I)*L*M
        A(I,2)= SX(I)*(M**2) + SY(I)*(L**2) - 2*SXY(I)*L*M
        A(I,3)= SZ(I)
        A(I,6)= -SX(I)*L*M + SY(I)*M*L + SXY(I)*(L**2 - M**2)
        A(I,5)= SYZ(I)*M + SXZ(I)*L
        A(I,4)= SYZ(I)*L - SXZ(I)*M
55    CONTINUE
      WRITE (13,10) 'NEL','S1','S2','S3','S6','S5','S4'
      DO 80 I=1,NEL
      WRITE (13,60) I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
80    CONTINUE
*
*SUBROUTINES FOR CALCULATING THE RELIABILITY ;
*----------------------------------------------------
      CALL BETA(A,B,NEL)
      WRITE (5,*) 'INPUT ALFA'
      READ  (5,*) ALF
      WRITE (13,*) 'ALFA :',ALF
      CALL ALFA(A,B,NEL,ALF)
      CALL RELI(A,B,NEL)
      CALL ELRE(B,NEL)
*
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
11    FORMAT (//,1X,A10,7(A7,4X) / 1X,80('-'))
15    FORMAT (1X,'THETA(',I2,')= ')
25    FORMAT (1X,'THETA(',I2,')= ',F6.1)
60    FORMAT (/,4X,I6,6E11.3)
61    FORMAT (/,4X,I6,6E11.3,3X,F6.1)
*
      STOP
      END
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
******************************
      SUBROUTINE BETA(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL X(COLS),X1C,X2C,X3C
*
* PLY STRESS - STRENGTH,RATIO CALCULATION :
*--------------------------------------
      WRITE (13,10) 'NEL','SR1','SR2','SR3','SR6','SR5','SR4'
*A. FOR THE PARENT STRUCTURE,
*--------------------------
```

```
      DO 90 I=1,NELP
C STRENGTH PROPERTIES FOR GRAPHITE EPOXY,
C............................................
         X(1)  = 15.0E4
         X(2)  = 0.4E4
         X(3)  = X(2)
         X(6)  = 0.68E4
         X(4)  = X(6)
         X(5)  = X(6)
         X1C = -15.0E4
         X2C = -2.46E4
         X3C = X2C
         IF (A(I,1).LT.0) X(1) = X1C
         IF (A(I,2).LT.0) X(2) = X2C
         IF (A(I,3).LT.0) X(3) = X3C
      DO 80 J=1,COLS
         B(I,J) = ABS(A(I,J) / X(J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
*B. FOR THE PATCH,
*-----------------
      N=NELP+1
      DO 100 I=N,NEL
C STRENGTH PROPERTIES FOR E-GLASS EPOXY,
C............................................
         X(1)  = 10.34E4
         X(2)  = 0.276E4
         X(3)  = X(2)
         X(6)  = 0.414E4
         X(4)  = X(6)
         X(5)  = X(6)
         X1C = -10.3E4
         X2C = -1.38E4
         X3C = X2C
         IF (A(I,1).LT.0) X(1) = X1C
         IF (A(I,2).LT.0) X(2) = X2C
         IF (A(I,3).LT.0) X(3) = X3C
      DO 95 J=1,COLS
         B(I,J) = ABS(A(I,J) / X(J))
95    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
100   CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END

**********************************
      SUBROUTINE ALFA(A,B,NEL,ALF)
**********************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
      REAL AREA(100),AMIN
*
* PLY STRESS - STRENGTH,RATIO RISED BY ALFA CALCULATION :
*---------------------------------------------------------
      WRITE (13,10) 'NEL','V1','V2','V3','V6','V5','V4'
      DO 90 I=1,NEL
      READ (17,*) IIEL,AREA(I),AMIN
```

```
          AMIN=400.
      WRITE (5,95) IIEL,AREA(I),AMIN
      WRITE (3,95) IIEL,AREA(I),AMIN
      DO 80 J=1,COLS
*         A(I,J) = B(I,J)**ALF
         A(I,J) = (B(I,J)**ALF)*AREA(I)/AMIN
80    CONTINUE
      WRITE (13,60)I,A(I,1),A(I,2),A(I,3),A(I,6),A(I,5),A(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
95    FORMAT (//1X,'AREA(',I2,') = ',2F10.2)
      RETURN
      END

******************************
      SUBROUTINE RELI(A,B,NEL)
******************************
      PARAMETER (ROWS=100,COLS=6)
      REAL*8 A(ROWS,COLS),B(ROWS,COLS)
*
* PLY STERSS TENSOR RELIABILITY CALCULATION (WEIBULL) :
*-----------------------------------------------------
      WRITE (13,10) 'NEL','R1','R2','R3','R6','R5','R4'
      DO 90 I=1,NEL
      DO 80 J=1,COLS
         B(I,J) = EXP(-A(I,J))
80    CONTINUE
      WRITE (13,60) I,B(I,1),B(I,2),B(I,3),B(I,6),B(I,5),B(I,4)
90    CONTINUE
10    FORMAT (//,1X,A10,6(A7,4X) / 1X,80('-'))
60    FORMAT (/,4X,I6,6E11.3)
      RETURN
      END
*****************************
      SUBROUTINE ELRE(B,NEL)
*****************************
      PARAMETER (ROWS=100,COLS=6,COLS1=7)
      REAL*8 B(ROWS,COLS),C(ROWS,COLS1),RT
*
*ELEMENTS RELIABILITY CALCUL., AS WELL AS "FIBER" (R1) AND "MATRIX"
*RELIABILITY CALCUL.& TOTAL STRUCTURE RELIABILITY CALCUL.
*------------------------------------------------------------
      WRITE (13,10)'NEL','R1','R2','R3','R6','R5','R4','RE'
      RT =1.0
      C(NEL+1,1)=1.0
      DO 90 I=1,NEL
      C(I,COLS1) = 1.0
      DO 80 J=1,COLS
           C(I,J)=B(I,J)
           C(I,COLS1) = C(I,COLS1) * C(I,J)
           C(NEL+1,J) = C(NEL+1,J) * C(I,J)
80    CONTINUE
      RT = RT * C(I,COLS1)
      WRITE (5,60) I,C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6),C(I,7)
      WRITE (13,60) I,C(I,1),C(I,2),C(I,3),C(I,4),C(I,5),C(I,6),C(I,7)
90    CONTINUE
      WRITE (13,10) 'TOTAL REL.:','RT1','RT2','RT3','RT6','RT5',
     &              'RT4','RT'
      WRITE (13,65) C(NEL+1,1),C(NEL+1,2),C(NEL+1,3),C(NEL+1,4),
     &                  C(NEL+1,5),C(NEL+1,6),RT
      WRITE (5,70) RT
      WRITE (13,70) RT
 10   FORMAT (//,1X,A10,7(A7,4X) / 1X,95('-'))
 60   FORMAT (/,4X,I6,7E11.3)
 65   FORMAT (/,11X,7E11.3)
 70   FORMAT (//,1X,'TOTAL STRUCTURE RELIABILITY = ',E11.3 /1X,40('='))
      RETURN
      END
```

```
INPUT STRESS FN = THM3D4.STR
INPUT ELEM. ANGLE FN = THM3D4.EL
INPUT  AREAS OF ELEMENTS FN =THM3D4.ARE
 OUTPUT FN =THM3D4.REL
OUTPUT :THM3D4.REL

      NEL     SX          SY          SZ          SXY         SXZ         SYZ        ANGLE
-------------------------------------------------------------------------------------------

        1 -0.277E+03  0.391E+05  0.187E+02 -0.235E+04  0.909E+00  0.622E+01       90.0

        2  0.279E+03  0.209E+05  0.160E+02  0.236E+04  0.849E+00  0.604E+01       75.0

        3  0.279E+03  0.209E+05  0.160E+02  0.236E+04 -0.849E+00 -0.604E+01       75.0

        4 -0.277E+03  0.391E+05  0.187E+02 -0.235E+04 -0.909E+00 -0.622E+01       90.0

        5 -0.278E+03  0.391E+05  0.248E+01 -0.235E+04  0.399E+00  0.675E+01       90.0

        6  0.279E+03  0.209E+05  0.217E+01  0.235E+04  0.361E+00  0.683E+01       75.0

        7  0.279E+03  0.209E+05  0.217E+01  0.235E+04 -0.361E+00 -0.683E+01       75.0

        8 -0.278E+03  0.391E+05  0.248E+01 -0.235E+04 -0.399E+00 -0.675E+01       90.0

        9 -0.278E+03  0.391E+05  0.653E-01 -0.235E+04  0.552E+01 -0.216E+02       90.0

       10  0.278E+03  0.209E+05 -0.746E+00  0.235E+04  0.553E+01 -0.216E+02       75.0

       11  0.278E+03  0.209E+05 -0.746E+00  0.235E+04 -0.553E+01  0.216E+02       75.0

       12 -0.278E+03  0.391E+05  0.653E-01 -0.235E+04 -0.552E+01  0.216E+02       90.0

       13 -0.278E+03  0.391E+05  0.113E+00 -0.235E+04  0.559E+01 -0.210E+02       90.0

       14  0.278E+03  0.209E+05 -0.692E+00  0.235E+04  0.559E+01 -0.210E+02       75.0

       15  0.278E+03  0.209E+05 -0.692E+00  0.235E+04 -0.559E+01  0.210E+02       75.0

       16 -0.278E+03  0.391E+05  0.113E+00 -0.235E+04 -0.559E+01  0.210E+02       90.0

       17 -0.278E+03  0.391E+05  0.250E+01 -0.235E+04 -0.992E+00 -0.434E+01       90.0

       18  0.279E+03  0.209E+05  0.218E+01  0.235E+04 -0.967E+00 -0.438E+01       75.0

       19  0.279E+03  0.209E+05  0.218E+01  0.235E+04  0.967E+00  0.438E+01       75.0

       20 -0.278E+03  0.391E+05  0.250E+01 -0.235E+04  0.992E+00  0.434E+01       90.0

       21 -0.278E+03  0.391E+05  0.190E+02 -0.236E+04 -0.608E+00 -0.566E+01       90.0

       22  0.277E+03  0.209E+05  0.163E+02  0.235E+04 -0.550E+00 -0.573E+01       75.0

       23  0.277E+03  0.209E+05  0.163E+02  0.235E+04  0.550E+00  0.573E+01       75.0

       24 -0.278E+03  0.391E+05  0.190E+02 -0.236E+04  0.608E+00  0.566E+01       90.0

       25 -0.318E+03  0.390E+05 -0.115E+03 -0.235E+04 -0.598E+01 -0.109E+01       90.0
```

```
26  0.243E+03  0.209E+05 -0.982E+02  0.235E+04 -0.607E+01 -0.414E+00     75.0
27  0.243E+03  0.209E+05 -0.982E+02  0.235E+04  0.607E+01  0.414E+00     75.0
28 -0.318E+03  0.390E+05 -0.115E+03 -0.235E+04  0.598E+01  0.109E+01     90.0
29 -0.320E+03  0.390E+05 -0.115E+03 -0.235E+04 -0.634E+01 -0.996E+00     90.0
30  0.241E+03  0.209E+05 -0.980E+02  0.235E+04 -0.621E+01 -0.305E+00     75.0
31  0.241E+03  0.209E+05 -0.980E+02  0.235E+04  0.621E+01  0.305E+00     75.0
32 -0.320E+03  0.390E+05 -0.115E+03 -0.235E+04  0.634E+01  0.996E+00     90.0
 1 -0.281E+03  0.391E+05 -0.594E+00 -0.235E+04  0.205E+01 -0.802E+01     90.0
 2  0.275E+03  0.209E+05 -0.107E+01  0.235E+04  0.204E+01 -0.800E+01     75.0
 3  0.275E+03  0.209E+05 -0.107E+01  0.235E+04 -0.204E+01  0.800E+01     75.0
 4 -0.281E+03  0.391E+05 -0.594E+00 -0.235E+04 -0.205E+01  0.802E+01     90.0
 5 -0.281E+03  0.391E+05 -0.646E+00 -0.235E+04  0.206E+01 -0.778E+01     90.0
 6  0.275E+03  0.209E+05 -0.117E+01  0.235E+04  0.206E+01 -0.781E+01     75.0
 7  0.275E+03  0.209E+05 -0.117E+01  0.235E+04 -0.206E+01  0.781E+01     75.0
 8 -0.281E+03  0.391E+05 -0.646E+00 -0.235E+04 -0.206E+01  0.778E+01     90.0
 9 -0.281E+03  0.391E+05  0.320E+00 -0.235E+04 -0.370E+00 -0.167E+01     90.0
10  0.275E+03  0.209E+05  0.274E+00  0.235E+04 -0.359E+00 -0.170E+01     75.0
11  0.275E+03  0.209E+05  0.274E+00  0.235E+04  0.359E+00  0.170E+01     75.0
12 -0.281E+03  0.391E+05  0.320E+00 -0.235E+04  0.370E+00  0.167E+01     90.0
13 -0.282E+03  0.391E+05  0.641E+01 -0.235E+04 -0.167E+00 -0.211E+01     90.0
14  0.274E+03  0.209E+05  0.552E+01  0.236E+04 -0.170E+00 -0.218E+01     75.0
15  0.274E+03  0.209E+05  0.552E+01  0.236E+04  0.170E+00  0.218E+01     75.0
16 -0.282E+03  0.391E+05  0.641E+01 -0.235E+04  0.167E+00  0.211E+01     90.0
17 -0.294E+03  0.391E+05 -0.422E+02 -0.236E+04 -0.238E+01 -0.128E+01     90.0
18  0.263E+03  0.209E+05 -0.361E+02  0.235E+04 -0.229E+01 -0.481E+00     75.0
19  0.263E+03  0.209E+05 -0.361E+02  0.235E+04  0.229E+01  0.481E+00     75.0
20 -0.294E+03  0.391E+05 -0.422E+02 -0.236E+04  0.238E+01  0.128E+01     90.0
21 -0.295E+03  0.390E+05 -0.416E+02 -0.235E+04 -0.202E+01 -0.119E+01     90.0
22  0.264E+03  0.209E+05 -0.356E+02  0.236E+04 -0.220E+01 -0.446E+00     75.0
23  0.264E+03  0.209E+05 -0.356E+02  0.236E+04  0.220E+01  0.446E+00     75.0
```

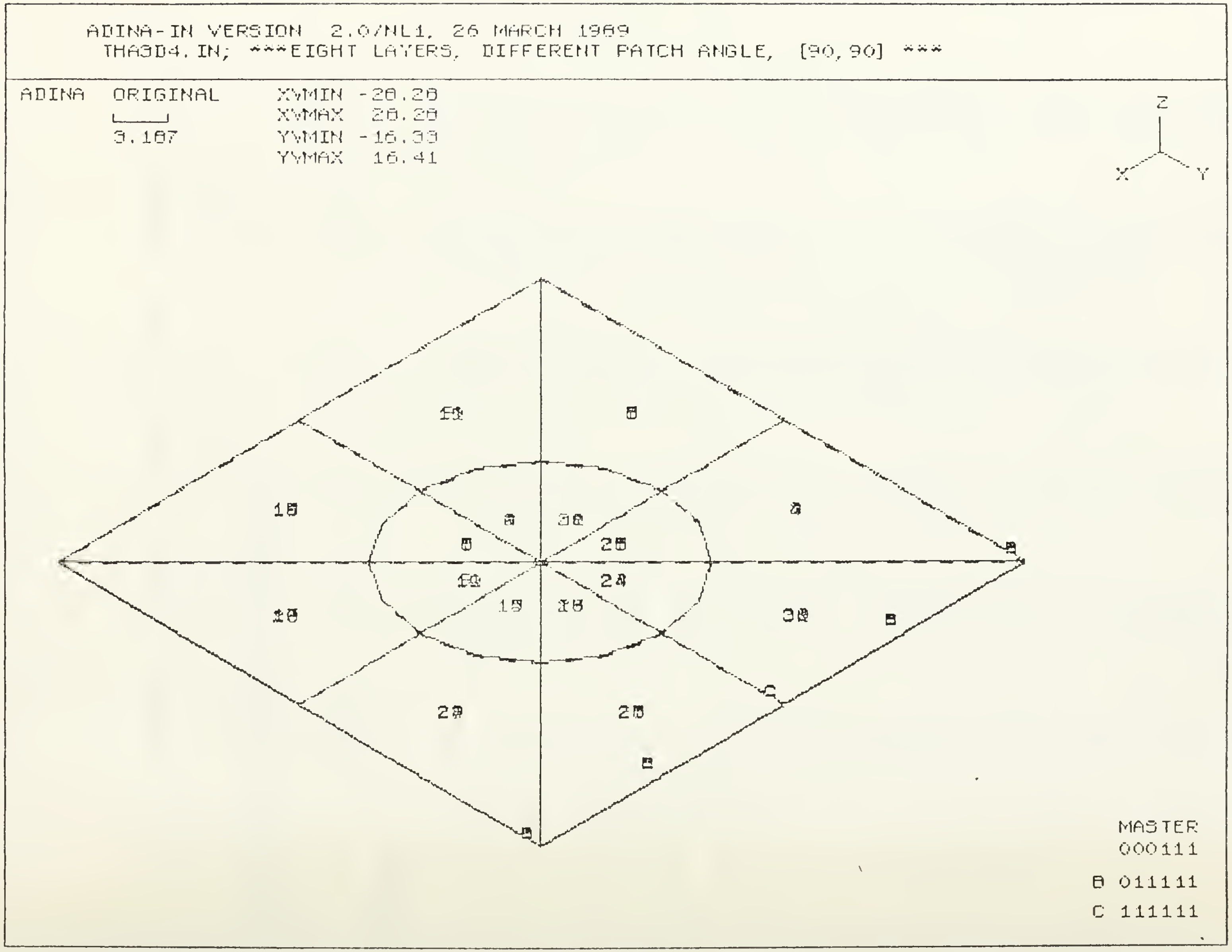
```
24 -0.295E+03  0.390E+05 -0.416E+02 -0.235E+04  0.202E+01  0.119E+01      90.0
25 -0.281E+03  0.391E+05  0.629E+01 -0.235E+04  0.323E+00  0.179E+01      90.0
26  0.275E+03  0.209E+05  0.535E+01  0.235E+04  0.293E+00  0.211E+01      75.0
27  0.275E+03  0.209E+05  0.535E+01  0.235E+04 -0.293E+00 -0.211E+01      75.0
28 -0.281E+03  0.391E+05  0.629E+01 -0.235E+04 -0.323E+00 -0.179E+01      90.0
29 -0.280E+03  0.391E+05  0.293E+00 -0.235E+04  0.130E+00  0.284E+01      90.0
30  0.276E+03  0.209E+05  0.287E+00  0.235E+04  0.140E+00  0.243E+01      75.0
31  0.276E+03  0.209E+05  0.287E+00  0.235E+04 -0.140E+00 -0.243E+01      75.0
32 -0.280E+03  0.391E+05  0.293E+00 -0.235E+04 -0.130E+00 -0.284E+01      90.0

NEL     S1          S2          S3          S6          S5          S4
------------------------------------------------------------------------------------

 1  0.391E+05 -0.277E+03  0.187E+02  0.235E+04  0.622E+01 -0.909E+00
 2  0.207E+05  0.485E+03  0.160E+02  0.313E+04  0.605E+01  0.743E+00
 3  0.207E+05  0.485E+03  0.160E+02  0.313E+04 -0.605E+01 -0.743E+00
 4  0.391E+05 -0.277E+03  0.187E+02  0.235E+04 -0.622E+01  0.909E+00
 5  0.391E+05 -0.278E+03  0.248E+01  0.235E+04  0.675E+01 -0.399E+00
 6  0.207E+05  0.486E+03  0.217E+01  0.313E+04  0.669E+01  0.142E+01
 7  0.207E+05  0.486E+03  0.217E+01  0.313E+04 -0.669E+01 -0.142E+01
 8  0.391E+05 -0.278E+03  0.248E+01  0.235E+04 -0.675E+01  0.399E+00
 9  0.391E+05 -0.278E+03  0.653E-01  0.235E+04 -0.216E+02 -0.552E+01
10  0.207E+05  0.485E+03 -0.746E+00  0.313E+04 -0.194E+02 -0.109E+02
11  0.207E+05  0.485E+03 -0.746E+00  0.313E+04  0.194E+02  0.109E+02
12  0.391E+05 -0.278E+03  0.653E-01  0.235E+04  0.216E+02  0.552E+01
13  0.391E+05 -0.278E+03  0.113E+00  0.235E+04 -0.210E+02 -0.559E+01
14  0.207E+05  0.485E+03 -0.692E+00  0.313E+04 -0.189E+02 -0.108E+02
15  0.207E+05  0.485E+03 -0.692E+00  0.313E+04  0.189E+02  0.108E+02
16  0.391E+05 -0.278E+03  0.113E+00  0.235E+04  0.210E+02  0.559E+01
17  0.391E+05 -0.278E+03  0.250E+01  0.235E+04 -0.434E+01  0.992E+00
18  0.207E+05  0.485E+03  0.218E+01  0.313E+04 -0.448E+01 -0.198E+00
19  0.207E+05  0.485E+03  0.218E+01  0.313E+04  0.448E+01  0.198E+00
```

```
20  0.391E+05 -0.278E+03  0.250E+01  0.235E+04  0.434E+01 -0.992E+00
21  0.391E+05 -0.278E+03  0.190E+02  0.236E+04 -0.566E+01  0.608E+00
22  0.207E+05  0.486E+03  0.163E+02  0.313E+04 -0.568E+01 -0.952E+00
23  0.207E+05  0.486E+03  0.163E+02  0.313E+04  0.568E+01  0.952E+00
24  0.391E+05 -0.278E+03  0.190E+02  0.236E+04  0.566E+01 -0.608E+00
25  0.390E+05 -0.318E+03 -0.115E+03  0.235E+04 -0.109E+01  0.598E+01
26  0.207E+05  0.450E+03 -0.982E+02  0.313E+04 -0.197E+01  0.575E+01
27  0.207E+05  0.450E+03 -0.982E+02  0.313E+04  0.197E+01 -0.575E+01
28  0.390E+05 -0.318E+03 -0.115E+03  0.235E+04  0.109E+01 -0.598E+01
29  0.390E+05 -0.320E+03 -0.115E+03  0.235E+04 -0.996E+00  0.634E+01
30  0.207E+05  0.449E+03 -0.980E+02  0.313E+04 -0.190E+01  0.592E+01
31  0.207E+05  0.449E+03 -0.980E+02  0.313E+04  0.190E+01 -0.592E+01
32  0.390E+05 -0.320E+03 -0.115E+03  0.235E+04  0.996E+00 -0.634E+01
33  0.391E+05 -0.281E+03 -0.594E+00  0.235E+04 -0.802E+01 -0.205E+01
34  0.207E+05  0.482E+03 -0.107E+01  0.313E+04 -0.720E+01 -0.404E+01
35  0.207E+05  0.482E+03 -0.107E+01  0.313E+04  0.720E+01  0.404E+01
36  0.391E+05 -0.281E+03 -0.594E+00  0.235E+04  0.802E+01  0.205E+01
37  0.391E+05 -0.281E+03 -0.646E+00  0.235E+04 -0.778E+01 -0.206E+01
38  0.207E+05  0.482E+03 -0.117E+01  0.313E+04 -0.701E+01 -0.401E+01
39  0.207E+05  0.482E+03 -0.117E+01  0.313E+04  0.701E+01  0.401E+01
40  0.391E+05 -0.281E+03 -0.646E+00  0.235E+04  0.778E+01  0.206E+01
41  0.391E+05 -0.281E+03  0.320E+00  0.235E+04 -0.167E+01  0.370E+00
42  0.207E+05  0.482E+03  0.274E+00  0.313E+04 -0.173E+01 -0.927E-01
43  0.207E+05  0.482E+03  0.274E+00  0.313E+04  0.173E+01  0.927E-01
44  0.391E+05 -0.281E+03  0.320E+00  0.235E+04  0.167E+01 -0.370E+00
45  0.391E+05 -0.282E+03  0.641E+01  0.235E+04 -0.211E+01  0.167E+00
46  0.207E+05  0.481E+03  0.552E+01  0.313E+04 -0.215E+01 -0.401E+00
47  0.207E+05  0.481E+03  0.552E+01  0.313E+04  0.215E+01  0.401E+00
48  0.391E+05 -0.282E+03  0.641E+01  0.235E+04  0.211E+01 -0.167E+00
49  0.391E+05 -0.294E+03 -0.422E+02  0.235E+04 -0.128E+01  0.238E+01
```

```
   50  0.207E+05  0.471E+03 -0.361E+02  0.313E+04 -0.106E+01  0.208E+01
   51  0.207E+05  0.471E+03 -0.361E+02  0.313E+04  0.106E+01 -0.208E+01
   52  0.391E+05 -0.294E+03 -0.422E+02  0.235E+04  0.128E+01 -0.238E+01
   53  0.390E+05 -0.295E+03 -0.416E+02  0.235E+04 -0.119E+01  0.202E+01
   54  0.207E+05  0.470E+03 -0.356E+02  0.313E+04 -0.100E+01  0.201E+01
   55  0.207E+05  0.470E+03 -0.356E+02  0.313E+04  0.100E+01 -0.201E+01
   56  0.390E+05 -0.295E+03 -0.416E+02  0.235E+04  0.119E+01 -0.202E+01
   57  0.391E+05 -0.281E+03  0.629E+01  0.235E+04  0.179E+01 -0.323E+00
   58  0.207E+05  0.482E+03  0.535E+01  0.313E+04  0.212E+01  0.264E+00
   59  0.207E+05  0.482E+03  0.535E+01  0.313E+04 -0.212E+01 -0.264E+00
   60  0.391E+05 -0.281E+03  0.629E+01  0.235E+04 -0.179E+01  0.323E+00
   61  0.391E+05 -0.280E+03  0.293E+00  0.235E+04  0.284E+01 -0.130E+00
   62  0.207E+05  0.483E+03  0.287E+00  0.313E+04  0.238E+01  0.493E+00
   63  0.207E+05  0.483E+03  0.287E+00  0.313E+04 -0.238E+01 -0.493E+00
   64  0.391E+05 -0.280E+03  0.293E+00  0.235E+04 -0.284E+01  0.130E+00

ALFA :    5.000000
      NEL     R1         R2         R3         R6         R5         R4         RE
--------------------------------------------------------------------------------------
        1  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
        2  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
        3  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
        4  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
        5  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
        6  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
        7  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
        8  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
        9  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
       10  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
       11  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
       12  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
```

```
13  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
14  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
15  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
16  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
17  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
18  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
19  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
20  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
21  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
22  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
23  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
24  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
25  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
26  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
27  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.898E+00  0.898E+00
28  0.997E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.974E+00  0.971E+00
29  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
30  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
31  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.931E+00  0.931E+00
32  0.998E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.983E+00  0.981E+00
33  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
34  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.978E+00
35  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.978E+00
36  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
37  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
38  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.978E+00
39  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.978E+00
40  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
41  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
42  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
```

```
      43  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      44  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      45  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      46  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      47  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      48  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      49  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      50  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      51  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      52  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      53  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      54  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.979E+00
      55  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.979E+00
      56  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      57  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      58  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      59  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.978E+00  0.978E+00
      60  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      61  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00
      62  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.978E+00
      63  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.979E+00  0.978E+00
      64  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.994E+00

TOTAL REL.    RT1        RT2        RT3        RT6        RT5        RT4         RT
-------------------------------------------------------------------------------------

           0.944E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.103E+00

TOTAL STRUCTURE RELIABILITY =   0.103E+00
====================================
```



ADINA-IN VERSION 2.0/NL1, 26 MARCH 1989
THA3D4.IN; ***EIGHT LAYERS, DIFFERENT PATCH ANGLE, [90,90] ***

ADINA ORIGINAL
3.187

XVMIN -20.20
XVMAX 20.20
YVMIN -16.33
YVMAX 16.41

MASTER
000111
B 011111
C 111111

```
*       A D I N A - I N   I N P U T   F I L E
*
* THA3D4.IN, EIGHT SYMMETRIC LAYERS, REPAIR W/ DIFFER. LAYUP ANGLE.
*
FILEUNITS LIST=8 LOG=7 ECHO=7
CONTROL PLOTUNIT=CM
COLORS BCODE=BLUE
*
DATABASE CREATE
WORKSTATION DEVICE=0
*
HEADING ' THA3D4.IN; ***EIGHT LAYERS, DIFFERENT PATCH ANGLE, [90,90] ***'
*
MASTER IDOF=000111
PRINTOUT VOLUME=MAXIMUM IPD=1 IPRIC=0 P=STRAINS
PORTHOLE FORMATTED=YES FILE=60
*
COORDINATES / ENTRIES NODE     X      Y      Z
                          1   -20.   -20.   0.1
                          2     0.   -20.   0.1
                          3    20.   -20.   0.1
                          4   -20.     0.   0.1
                          5     0.     0.   0.1
                          6    20.     0.   0.1
                          7   -20.    20.   0.1
                          8     0.    20.   0.1
                          9    20.    20.   0.1
                         21   -20.   -20.   0.
                         22     0.   -20.   0.
                         23    20.   -20.   0.
                         24   -20.     0.   0.
                         25     0.     0.   0.
                         26    20.     0.   0.
                         27   -20.    20.   0.
                         28     0.    20.   0.
                         29    20.    20.   0.
                        101     5.     0.   0.
                        102     0.    10.   0.
                        103     5.    10.   0.
                        104    15.      2.68 0.
                        105      7.68  10.    0.
                        106    15.     10.    0.
                        107    15.    -10.    0.
*=====================================================
*NOTE THE MAXES MEAN : 1=90DEG 2=15 3=75 4=45 5=-45
*=====================================================
MATERIAL 1 ORTHOTROPIC 181.E05 10.3E05 10.3E05 0.0159 0.0159 0.28,
                        GAB=7.17E05 7.17E05 7.17E05
*
SYSTEM 1 CYLINDRIC X=0 Y=0 Z=0 PHI=0 THETA=-90. XSI=90.
COORDINATES / ENTRIES NODES R THETA       XL
                        10     10.  0.        0.1
                        11     10.  45.       0.1
                        12     10.  90.       0.1
                        13     10.  135.      0.1
                        14     10.  180.      0.1
                        15     10.  225.      0.1
                        16     10.  270.      0.1
                        17     10.  315.      0.1
```

```
                      18    10.  360.   0.1
                      30    10.  0.     0.
                      31    10.  45.    0.
                      32    10.  90.    0.
                      33    10.  135.   0.
                      34    10.  180.   0.
                      35    10.  225.   0.
                      36    10.  270.   0.
                      37    10.  315.   0.
                      38    10.  360.   0.
*
LINE CYLINDRIC 11 10 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 12 11 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 13 12 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 14 13 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 15 14 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 16 15 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 17 16 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 18 17 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 31 30 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 32 31 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 33 32 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 34 33 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 35 34 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 36 35 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 37 36 EL=1 MIDNODES=1 NC=A
LINE CYLINDRIC 38 37 EL=1 MIDNODES=1 NC=A
*
EGROUP 1 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 7 4 18 17 27 24 38 37 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 4 1 11 10 24 21 31 30 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 1 2 12 11 21 22 32 31 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 2 3 13 12 22 23 33 32 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 3 6 14 13 23 26 34 33 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 6 9 15 14 26 29 35 34 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 9 8 16 15 29 28 36 35 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 8 7 17 16 28 27 37 36 EL1=1 EL2=1 EL3=4 NODES=27
GSURFACE 7 8 28 27   EL1=1 EL2=4 NO=9
GSURFACE 8 9 29 28   EL1=1 EL2=4 NO=9
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                 1     1      1
  STEP 4 TO
                 29    1      1
                 2     1      3
  STEP 4 TO
                 30    1      3
                 3     1      3
  STEP 4 TO
                 31    1      3
                 4     1      1
  STEP 4 TO
                 32    1      1
*
```

```
LOADS ELEMENT
              9  2  -3.0E04
         TO
              16  2  -3.0E04

*
FIXB 123 LINES / 8 28
FIXB 23 SURFACES /  7 8 28 27 / 8 9 29 28
*
*
EGROUP 2 THREEDSOLID MATERIAL=1 TABLES
GVOLUME 11 12 5 5 31 32 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 12 13 5 5 32 33 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 13 14 5 5 33 34 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 14 15 5 5 34 35 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 15 16 5 5 35 36 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 16 17 5 5 36 37 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 17 18 5 5 37 38 25 25 EL1=1 EL2=1 EL3=4 NODES=27
GVOLUME 10 11 5 5 30 31 25 25 EL1=1 EL2=1 EL3=4 NODES=27
AXES-ORTHOTROPIC 1 NODI=101 NODJ=103 NODK=102
AXES-ORTHOTROPIC 2 NODI=101 NODJ=104 NODK=102
AXES-ORTHOTROPIC 3 NODI=101 NODJ=105 NODK=102
AXES-ORTHOTROPIC 4 NODI=101 NODJ=106 NODK=102
AXES-ORTHOTROPIC 5 NODI=101 NODJ=107 NODK=102
*STRESSTABLE 1 1 2 3 4 5 6 7 8 21 26 27
STRESSTABLE 1  21
EDATA / ENTRIES EL TABLE MAXES
                1    1     1
  STEP 4 TO
                29   1     1
                2    1     1
  STEP 4 TO
                30   1     1
                3    1     1
  STEP 4 TO
                31   1     1
                4    1     1
  STEP 4 TO
                32   1     1
*
*
EGZONE NAME=THREEDSOLID / 1 / 2
FRAME-HEADING=UPPER XSF=1.0 YSF=0.5 XFMAX=22.5 YFMAX=17.0
MESH ZONE=THREEDSOLID NODES=0 ELEMENT=1 HIDDEN=DASHED BCODE=ALL
*
ADINA
*
END
```

```
INPUT STRESS FN = THA3D4.STR
INPUT ELEM. ANGLE FN = THA3D4.EL
INPUT  AREAS OF ELEMENTS FN =THA3D4.ARE
 OUTPUT FN =THA3D4.REL
OUTPUT :THA3D4.REL

      NEL     SX           SY           SZ          SXY          SXZ          SYZ      ANGLE
----------------------------------------------------------------------------------------

       1 -0.336E+02  0.371E+05 -0.470E+00 -0.197E+04  0.142E+01  0.316E+01      90.0
       2  0.690E+03  0.216E+05 -0.521E+00  0.295E+04  0.133E+01  0.322E+01      75.0
       3  0.690E+03  0.216E+05 -0.521E+00  0.295E+04 -0.133E+01 -0.322E+01      75.0
       4 -0.336E+02  0.371E+05 -0.470E+00 -0.197E+04 -0.142E+01 -0.316E+01      90.0
       5 -0.722E+03  0.382E+05  0.137E+02 -0.203E+04 -0.123E+01  0.284E+01      90.0
       6 -0.759E+02  0.215E+05  0.158E+02  0.279E+04 -0.666E+00  0.504E+01      75.0
       7 -0.759E+02  0.215E+05  0.158E+02  0.279E+04  0.666E+00 -0.504E+01      75.0
       8 -0.722E+03  0.382E+05  0.137E+02 -0.203E+04  0.123E+01 -0.284E+01      90.0
       9 -0.530E+03  0.393E+05  0.120E+02 -0.228E+04  0.801E+00 -0.160E+02      90.0
      10  0.468E+02  0.213E+05  0.137E+02  0.248E+04  0.433E+01 -0.165E+02      75.0
      11  0.468E+02  0.213E+05  0.137E+02  0.248E+04 -0.433E+01  0.165E+02      75.0
      12 -0.530E+03  0.393E+05  0.120E+02 -0.228E+04 -0.801E+00  0.160E+02      90.0
      13 -0.189E+03  0.397E+05 -0.200E+02 -0.241E+04  0.390E+01 -0.153E+02      90.0
      14  0.380E+03  0.213E+05 -0.166E+02  0.238E+04  0.407E+01 -0.166E+02      75.0
      15  0.380E+03  0.213E+05 -0.166E+02  0.238E+04 -0.407E+01  0.166E+02      75.0
      16 -0.189E+03  0.397E+05 -0.200E+02 -0.241E+04 -0.390E+01  0.153E+02      90.0
      17  0.166E+02  0.378E+05 -0.109E+02 -0.223E+04 -0.117E+01 -0.141E+01      90.0
      18  0.627E+03  0.208E+05 -0.882E+01  0.250E+04 -0.172E+01 -0.371E+01      75.0
      19  0.627E+03  0.208E+05 -0.882E+01  0.250E+04  0.172E+01  0.371E+01      75.0
      20  0.166E+02  0.378E+05 -0.109E+02 -0.223E+04  0.117E+01  0.141E+01      90.0
      21 -0.564E+03  0.377E+05  0.347E+02 -0.209E+04  0.981E+00 -0.526E+01      90.0
      22  0.411E+02  0.209E+05  0.344E+02  0.260E+04  0.167E+00 -0.618E+01      75.0
      23  0.411E+02  0.209E+05  0.344E+02  0.260E+04 -0.167E+00  0.618E+01      75.0
      24 -0.564E+03  0.377E+05  0.347E+02 -0.209E+04 -0.981E+00  0.526E+01      90.0
      25 -0.293E+03  0.375E+05 -0.101E+03 -0.243E+04 -0.309E+01 -0.679E+01      90.0
```

```
26  0.146E+03  0.192E+05 -0.844E+02  0.187E+04 -0.457E+01 -0.428E+01    75.0
27  0.146E+03  0.192E+05 -0.844E+02  0.187E+04  0.457E+01  0.428E+01    75.0
28 -0.293E+03  0.375E+05 -0.101E+03 -0.243E+04  0.309E+01  0.679E+01    90.0
29  0.120E+02  0.418E+05 -0.140E+03 -0.252E+04 -0.267E+01 -0.487E+01    90.0
30  0.664E+03  0.227E+05 -0.122E+03  0.265E+04 -0.502E+01 -0.298E+01    75.0
31  0.664E+03  0.227E+05 -0.122E+03  0.265E+04  0.502E+01  0.298E+01    75.0
32  0.120E+02  0.418E+05 -0.140E+03 -0.252E+04  0.267E+01  0.487E+01    90.0
 1 -0.123E+03  0.308E+05 -0.208E+02 -0.538E+03 -0.223E+01  0.212E+01    90.0
 2 -0.127E+03  0.308E+05 -0.350E+02 -0.538E+03 -0.696E+00  0.155E+01    90.0
 3 -0.127E+03  0.308E+05 -0.350E+02 -0.538E+03  0.696E+00 -0.155E+01    90.0
 4 -0.123E+03  0.308E+05 -0.208E+02 -0.538E+03  0.223E+01 -0.212E+01    90.0
 5 -0.874E+02  0.301E+05  0.748E+02 -0.690E+03 -0.302E+01  0.302E+01    90.0
 6 -0.913E+02  0.301E+05  0.613E+02 -0.690E+03 -0.329E+00  0.357E+01    90.0
 7 -0.913E+02  0.301E+05  0.613E+02 -0.690E+03  0.329E+00 -0.357E+01    90.0
 8 -0.874E+02  0.301E+05  0.748E+02 -0.690E+03  0.302E+01 -0.302E+01    90.0
 9 -0.698E+02  0.300E+05  0.499E+02 -0.775E+03 -0.306E+01  0.358E+01    90.0
10 -0.728E+02  0.300E+05  0.393E+02 -0.775E+03 -0.124E+01  0.457E+01    90.0
11 -0.728E+02  0.300E+05  0.393E+02 -0.775E+03  0.124E+01 -0.457E+01    90.0
12 -0.698E+02  0.300E+05  0.499E+02 -0.775E+03  0.306E+01 -0.358E+01    90.0
13 -0.488E+02  0.299E+05 -0.410E+02 -0.810E+03  0.150E+01 -0.539E+01    90.0
14 -0.517E+02  0.299E+05 -0.514E+02 -0.810E+03  0.943E+00 -0.355E+01    90.0
15 -0.517E+02  0.299E+05 -0.514E+02 -0.810E+03 -0.943E+00  0.355E+01    90.0
16 -0.488E+02  0.299E+05 -0.410E+02 -0.810E+03 -0.150E+01  0.539E+01    90.0
17 -0.822E+02  0.302E+05 -0.545E+02 -0.768E+03  0.178E+01 -0.117E+02    90.0
18 -0.849E+02  0.301E+05 -0.640E+02 -0.769E+03  0.309E+00 -0.996E+01    90.0
19 -0.849E+02  0.301E+05 -0.640E+02 -0.769E+03 -0.309E+00  0.996E+01    90.0
20 -0.822E+02  0.302E+05 -0.545E+02 -0.768E+03 -0.178E+01  0.117E+02    90.0
21 -0.128E+03  0.309E+05  0.374E+02 -0.668E+03  0.724E+00 -0.125E+02    90.0
22 -0.130E+03  0.309E+05  0.298E+02 -0.668E+03  0.211E+00 -0.116E+02    90.0
23 -0.130E+03  0.309E+05  0.298E+02 -0.668E+03 -0.211E+00  0.116E+02    90.0
```

```
 24 -0.128E+03  0.309E+05  0.374E+02 -0.668E+03 -0.724E+00  0.125E+02     90.0
 25 -0.162E+03  0.315E+05  0.563E+02 -0.620E+03  0.193E+01 -0.617E+01     90.0
 26 -0.165E+03  0.315E+05  0.456E+02 -0.620E+03  0.117E+01 -0.485E+01     90.0
 27 -0.165E+03  0.315E+05  0.456E+02 -0.620E+03 -0.117E+01  0.485E+01     90.0
 28 -0.162E+03  0.315E+05  0.563E+02 -0.620E+03 -0.193E+01  0.617E+01     90.0
 29 -0.163E+03  0.314E+05 -0.605E+02 -0.589E+03 -0.297E+01  0.613E+01     90.0
 30 -0.166E+03  0.314E+05 -0.699E+02 -0.589E+03 -0.114E+01  0.337E+01     90.0
 31 -0.166E+03  0.314E+05 -0.699E+02 -0.589E+03  0.114E+01 -0.337E+01     90.0
 32 -0.163E+03  0.314E+05 -0.605E+02 -0.589E+03  0.297E+01 -0.613E+01     90.0

 NEL      S1          S2          S3          S6          S5          S4
-----------------------------------------------------------------------------

   1  0.371E+05 -0.336E+02 -0.470E+00  0.197E+04  0.316E+01 -0.142E+01
   2  0.216E+05  0.612E+03 -0.521E+00  0.266E+04  0.345E+01 -0.451E+00
   3  0.216E+05  0.612E+03 -0.521E+00  0.266E+04 -0.345E+01  0.451E+00
   4  0.371E+05 -0.336E+02 -0.470E+00  0.197E+04 -0.316E+01  0.142E+01
   5  0.382E+05 -0.722E+03  0.137E+02  0.203E+04  0.284E+01  0.123E+01
   6  0.214E+05 -0.249E+02  0.158E+02  0.298E+04  0.470E+01  0.195E+01
   7  0.214E+05 -0.249E+02  0.158E+02  0.298E+04 -0.470E+01 -0.195E+01
   8  0.382E+05 -0.722E+03  0.137E+02  0.203E+04 -0.284E+01 -0.123E+01
   9  0.393E+05 -0.530E+03  0.120E+02  0.228E+04 -0.160E+02 -0.801E+00
  10  0.211E+05  0.229E+03  0.137E+02  0.316E+04 -0.148E+02 -0.845E+01
  11  0.211E+05  0.229E+03  0.137E+02  0.316E+04  0.148E+02  0.845E+01
  12  0.393E+05 -0.530E+03  0.120E+02  0.228E+04  0.160E+02  0.801E+00
  13  0.397E+05 -0.189E+03 -0.200E+02  0.241E+04 -0.153E+02 -0.390E+01
  14  0.211E+05  0.589E+03 -0.166E+02  0.316E+04 -0.150E+02 -0.823E+01
  15  0.211E+05  0.589E+03 -0.166E+02  0.316E+04  0.150E+02  0.823E+01
  16  0.397E+05 -0.189E+03 -0.200E+02  0.241E+04  0.153E+02  0.390E+01
  17  0.378E+05  0.166E+02 -0.109E+02  0.223E+04 -0.141E+01  0.117E+01
  18  0.207E+05  0.730E+03 -0.882E+01  0.289E+04 -0.403E+01  0.704E+00
  19  0.207E+05  0.730E+03 -0.882E+01  0.289E+04  0.403E+01 -0.704E+00
```

```
20  0.378E+05  0.166E+02 -0.109E+02  0.223E+04  0.141E+01 -0.117E+01
21  0.377E+05 -0.564E+03  0.347E+02  0.209E+04 -0.526E+01 -0.981E+00
22  0.208E+05  0.140E+03  0.344E+02  0.297E+04 -0.592E+01 -0.176E+01
23  0.208E+05  0.140E+03  0.344E+02  0.297E+04  0.592E+01  0.176E+01
24  0.377E+05 -0.564E+03  0.347E+02  0.209E+04  0.526E+01  0.981E+00
25  0.375E+05 -0.293E+03 -0.101E+03  0.243E+04 -0.679E+01  0.309E+01
26  0.189E+05  0.488E+03 -0.844E+02  0.315E+04 -0.532E+01  0.331E+01
27  0.189E+05  0.488E+03 -0.844E+02  0.315E+04  0.532E+01 -0.331E+01
28  0.375E+05 -0.293E+03 -0.101E+03  0.243E+04  0.679E+01 -0.309E+01
29  0.418E+05  0.120E+02 -0.140E+03  0.252E+04 -0.487E+01  0.267E+01
30  0.226E+05  0.818E+03 -0.122E+03  0.323E+04 -0.418E+01  0.407E+01
31  0.226E+05  0.818E+03 -0.122E+03  0.323E+04  0.418E+01 -0.407E+01
32  0.418E+05  0.120E+02 -0.140E+03  0.252E+04  0.487E+01 -0.267E+01
33  0.308E+05 -0.123E+03 -0.208E+02  0.538E+03  0.212E+01  0.223E+01
34  0.308E+05 -0.127E+03 -0.350E+02  0.538E+03  0.155E+01  0.696E+00
35  0.308E+05 -0.127E+03 -0.350E+02  0.538E+03 -0.155E+01 -0.696E+00
36  0.308E+05 -0.123E+03 -0.208E+02  0.538E+03 -0.212E+01 -0.223E+01
37  0.301E+05 -0.874E+02  0.748E+02  0.690E+03  0.302E+01  0.302E+01
38  0.301E+05 -0.913E+02  0.613E+02  0.690E+03  0.357E+01  0.329E+00
39  0.301E+05 -0.913E+02  0.613E+02  0.690E+03 -0.357E+01 -0.329E+00
40  0.301E+05 -0.874E+02  0.748E+02  0.690E+03 -0.302E+01 -0.302E+01
41  0.300E+05 -0.698E+02  0.499E+02  0.775E+03  0.358E+01  0.306E+01
42  0.300E+05 -0.728E+02  0.393E+02  0.775E+03  0.457E+01  0.124E+01
43  0.300E+05 -0.728E+02  0.393E+02  0.775E+03 -0.457E+01 -0.124E+01
44  0.300E+05 -0.698E+02  0.499E+02  0.775E+03 -0.358E+01 -0.306E+01
45  0.299E+05 -0.488E+02 -0.410E+02  0.810E+03 -0.539E+01 -0.150E+01
46  0.299E+05 -0.517E+02 -0.514E+02  0.810E+03 -0.355E+01 -0.943E+00
47  0.299E+05 -0.517E+02 -0.514E+02  0.810E+03  0.355E+01  0.943E+00
48  0.299E+05 -0.488E+02 -0.410E+02  0.810E+03  0.539E+01  0.150E+01
49  0.302E+05 -0.822E+02 -0.545E+02  0.768E+03 -0.117E+02 -0.178E+01
```

```
     50  0.301E+05 -0.849E+02 -0.640E+02  0.769E+03 -0.996E+01 -0.309E+00
     51  0.301E+05 -0.849E+02 -0.640E+02  0.769E+03  0.996E+01  0.309E+00
     52  0.302E+05 -0.822E+02 -0.545E+02  0.768E+03  0.117E+02  0.178E+01
     53  0.309E+05 -0.128E+03  0.374E+02  0.668E+03 -0.125E+02 -0.724E+00
     54  0.309E+05 -0.130E+03  0.298E+02  0.668E+03 -0.116E+02 -0.211E+00
     55  0.309E+05 -0.130E+03  0.298E+02  0.668E+03  0.116E+02  0.211E+00
     56  0.309E+05 -0.128E+03  0.374E+02  0.668E+03  0.125E+02  0.724E+00
     57  0.315E+05 -0.162E+03  0.563E+02  0.620E+03 -0.617E+01 -0.193E+01
     58  0.315E+05 -0.165E+03  0.456E+02  0.620E+03 -0.485E+01 -0.117E+01
     59  0.315E+05 -0.165E+03  0.456E+02  0.620E+03  0.485E+01  0.117E+01
     60  0.315E+05 -0.162E+03  0.563E+02  0.620E+03  0.617E+01  0.193E+01
     61  0.314E+05 -0.163E+03 -0.605E+02  0.589E+03  0.613E+01  0.297E+01
     62  0.314E+05 -0.166E+03 -0.699E+02  0.589E+03  0.337E+01  0.114E+01
     63  0.314E+05 -0.166E+03 -0.699E+02  0.589E+03 -0.337E+01 -0.114E+01
     64  0.314E+05 -0.163E+03 -0.605E+02  0.589E+03 -0.613E+01 -0.297E+01
ALFA :    5.000000
     NEL      R1         R2         R3         R6         R5         R4         RE
--------------------------------------------------------------------------------------------

      1  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00
      2  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.996E+00  0.996E+00
      3  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.996E+00  0.996E+00
      4  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00
      5  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00
      6  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.995E+00
      7  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.995E+00
      8  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00
      9  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
     10  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.990E+00
     11  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.990E+00
     12  0.999E+00  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
     13  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
```

```
14  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
15  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
16  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
17  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
18  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
19  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.994E+00  0.994E+00
20  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.998E+00
21  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00
22  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.995E+00
23  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.995E+00  0.995E+00
24  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.999E+00  0.999E+00
25  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.997E+00  0.997E+00
26  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
27  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.991E+00  0.991E+00
28  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.997E+00  0.997E+00
29  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
30  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.993E+00  0.993E+00
31  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.993E+00  0.993E+00
32  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.998E+00  0.997E+00
33  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
34  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
35  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
36  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
37  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
38  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
39  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
40  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
41  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
42  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
43  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
```

```
        44  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        45  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        46  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        47  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        48  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        49  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        50  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        51  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        52  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        53  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        54  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        55  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        56  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        57  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        58  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        59  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        60  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        61  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        62  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        63  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01
        64  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01  0.100E+01

TOTAL REL.   RT1        RT2        RT3        RT6        RT5        RT4        RT
---------------------------------------------------------------------------------------

             0.992E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.000E+00  0.873E+00

TOTAL STRUCTURE RELIABILITY =   0.873E+00
========================================
```

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